SUMMARY REPORT

OF THE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR

1912

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EXCELLENT MAJESTY
1914

To His Royal Highness the Duke of Connaught and Strathearn, K.G., &c., &c., &c., Governor General of Canada.

MAY IT PLEASE YOUR ROYAL HIGHNESS,—

The undersigned has the honour to lay before Your Royal Highness—in compliance with 6-7 Edward VII, chapter 29, section 18—the Summary Report of the operations of the Geological Survey during the calendar year 1912.

(Signed) LOUIS CODERRE,
Minister of Mines.

To the Hon. LOUIS CODERRE, M.P.,
Minister of Mines,
Ottawa.

SIR,—I have the honour to transmit, herewith, my summary report of the operations of the Geological Survey for the calendar year 1912, which includes the reports of the various officials on the work accomplished by them.

I have the honour to be, sir,

Your obedient servant,

(Signed) R. W. BROCK,
Director Geological Survey.

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SUMMARY REPORT

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To Dr. A. P. Low,
Deputy Minister of Mines,
Department of Mines,
Ottawa.

Sir,—I have the honour to submit herewith a summary report on the operations of the Geological Survey for the calendar year 1912.

CHANGES IN PERSONNEL.

The following changes have taken place in the staff during the year: *Resignations:* Dr. P. E. Raymond, Invertebrate Palæontologist; S. N. Graham, Assistant Curator of Mineralogy; G. G. Aitkens, Draughtsman. *Transferred to Mines Branch:* J. H. Fortune, messenger. *Death:* Mrs. J. Alexander; Dr. J. D. Trueman. *Appointments:* Dr. E. M. Kindle, Invertebrate Palæontologist; W. C. Cunningham, Cartographer; Anna V. Moffatt, Ida C. Taverner, and Florence H. B. Richardson, stenographers; A. E. Willis, messenger.

FIELD WORK.

In addition to the usual field work, special attention during the past season was given to the geology along the main lines of transportation in preparation for the visit of geologists from all parts of the world to Canada during the summer of 1913. While much of these lines have been covered by previous work, important sections remained unexamined, and these were filled in by the work last summer. One important result is that, for the first time, there is a complete geological section across the Canadian Cordillera, from Vancouver to Banff, along the Canadian Pacific railway.

From its nature, much of the field work of the Survey is necessarily attended by a certain amount of danger, though fortunately very few serious accidents have been recorded. The past season has, however, been an exception, and I regret to report that three serious accidents occurred.

Dr. J. D. Trueman, in charge of a geological party in the Rainy River district, was drowned in the Seine river at Steeprock lake through the upsetting of a canoe

in a rapid. Mr. Trueman had been employed by the Survey for many seasons, and was about to be appointed to the permanent staff. He was one of the most brilliant of the younger geologists, and had received an unusually thorough training for his work. His death is a great loss to the Survey, and, it is not too much to say, to the science of geology. His student assistant, J. K. Knox, deserves mention for the presence of mind and heroism he displayed. He risked his life in an endeavour to assist his chief, and he succeeded in bringing the other occupant of the canoe, Dr. Charles H. Walcott, to shore.

A second canoe accident, also fatal, happened in a rapid on the Bell river in northern Quebec, one of the canoemen losing his life.

A topographer, in charge of one of the British Columbia parties, was attacked by a grizzly bear, but fortunately escaped without fatal injuries. He was confined to the hospital for several months, but is able to again take up field work.

The field work undertaken by the Survey during the past year was as follows:—

GEOLOGICAL DIVISION.

Mr. D. D. Cairnes completed the geological section along the 141st parallel between the Yukon and Porcupine rivers. This is part of a geological section across the northern Cordillera undertaken in co-operation with the United States Geological Survey, which assumed responsibility for that portion between the Porcupine and the Arctic ocean. This section is being made as a reference section for the correlation of the geological formations of Alaska and the Yukon district. The most interesting result of Mr. Cairnes' work is the recognition of the Cambrian formation in this section, which consists of dominantly sedimentary rocks of Mesozoic, Palæozoic, and Pre-Cambrian age; the entire Palæozoic appears to be represented.

Mr. R. G. McConnell examined the quartz veins of Princess Royal island, studied the recent mining developments of Texada island, and made a geological section along the Grand Trunk Pacific railway between Prince Rupert and Aldermere.

Mr. G. H. Malloch continued his reconnaissance of the Groundhog coal basin at the head-waters of the Skeena river, determining the southern, eastern, and northern boundaries of this coal area.

Mr. C. H. Clapp was engaged in geologically surveying the areas covered by the Sooke and Duncan topographical map sheets, on Vancouver island, in which copper-bearing gabbros, of possible economic interest, occur. He also spent a few weeks studying the coal basins of Graham island, the largest island of the Queen Charlotte group. These basins, while smaller and more disturbed than had been hoped, are well worth careful prospecting on account of the excellent quality of the coal contained in them.

Mr. Chas. Camsell was engaged in examining copper and gold-copper deposits in the Similkameen district, and the coal-bearing rocks of White lake, Okanagan valley.

Mr. N. L. Bowen studied the geological section along the Canadian Pacific railway between Vancouver and Lytton.

Mr. A. M. Bateman made a preliminary examination of the economic resources of the Bridge River district, and a reconnaissance trip to Chilko lake, outlining the eastern edge of the Coast Range batholith.

Mr. B. Rose examined the Tertiary rocks about the west end of Kamloops lake, where prospecting for copper is being conducted.

Mr. C. W. Drysdale mapped a section 10 miles wide along the Thompson river valley between Sixmile point, Kamloops lake, and Lytton.

Mr. O. E. LeRoy was engaged in supervising field work in southern British Columbia.

Mr. Chas. D. Walcott continued his investigations of last season of the Cambrian of the Rocky Mountains along the Yellowhead pass. The remarkable palæontological discoveries made in these rocks in the Kicking Horse pass have been mentioned in preceding reports.

Mr. R. A. Daly completed his geological section through the Selkirk Mountain system, along the main line of the Canadian Pacific railway.

Mr. J. A. Allan completed the geological section through the Canadian Rockies, between Golden and Banff, along the Canadian Pacific railway.

Mr. S. J. Schofield studied the geology of the area between Crowsnest railway and the International Boundary line between Kootenay lake and the Kootenay river, East Kootenay, including the mining district about Moyie.

Mr. H. Ries continued the investigation of the clay shale deposits of British Columbia and western Alberta.

Mr. W. W. Leach made a detailed study of the Blairmore coal district.

Mr. J. D. Mackenzie was assigned to the coal area lying in the foot-hills between South Forks river and Pincher creek.

Mr. D. B. Dowling was engaged in collecting information regarding the coal reserves of Canada, and incidentally made a reconnaissance of several new coal fields, including Flathead river, the Coteau of southern Saskatchewan, and an area east of the Brazeau field on the Saskatchewan river.

Mr. C. H. Sternberg made collections of vertebrates from the richly fossiliferous Edmonton beds of the Red Deer river.

Mr. E. M. Kindle was engaged in examining the Palæozoic rocks of northern Manitoba.

Mr. Alex. McLean mapped some of the beaches of glacial lake Agassiz, and collected fossils at Stonewall and Stony mountain, in Manitoba. He also carried out some work at Munson, Alberta.

Messrs. E. S. Moore and R. C. Wallace made a reconnaissance of the district east of Lake Winnipeg between the Bloodvein and English rivers, in which considerable prospecting for gold is now being carried on.

Mr. J. D. Trueman was continuing the geological mapping of the Rainy River sheet. After his untimely death, Mr. W. L. Uglow took up the work to complete the information necessary for a guide book, for the International Geological Congress, between Port Arthur and Fort Francis, on the Canadian Northern railway.

Mr. W. H. Collins continued, and almost completed, the geological mapping of the Onaping map sheet, which covers the area north of that included in the Sudbury sheet.

Mr. W. A. Johnston completed his Beaverton, Sutton, and Barrie sheets, in the Lake Simcoe district.

Mr. M. Y. Williams was occupied with stratigraphic and palæontological studies on the Silurian of the eastern portion of Manitoulin island, and the Hamilton formation of Lambton county.

Mr. C. R. Stauffer completed his examination of the Devonian and higher Silurian formations of western Ontario.

Mr. J. Stansfield mapped and collected fossils in the districts in the vicinity of Credit Forks, Streetsville, Guelph, and Hamilton, Ontario, and Montreal, Que.

Mr. F. B. Taylor continued his studies on the surface geology of southern Ontario.

Mr. M. E. Wilson made a geological reconnaissance from Lake Kipawa via Grand Lake Victoria, to the head-waters of the Nottaway river, a region in which it had been hoped that mineral deposits similar to those of northern Ontario might be found. None, however, of present commercial importance were seen.

Mr. H. C. Cooke was engaged in a reconnaissance survey in northwestern Quebec on the head-waters of the Broadback river, between Lake Evans and Lake Mistassini.

Mr. Aug. Foerste was engaged in studying certain lower Palæozoic faunas of Quebec and Ontario.

Mr. P. E. Raymond was similarly occupied.

Mr. Robt. Harvie made a geological section across Brome county, between Knowlton Landing and Sweetsburg, to secure a better knowledge of the relationships of the older formations in which important copper deposits occur.

Mr. J. W. Goldthwait was occupied in working out certain problems connected with the recent geological history of the St. Lawrence valley.

Mr. Joseph Keele examined clay and shale deposits in the Provinces of Quebec and New Brunswick.

Mr. G. A. Young was engaged in completing the information required for the guide books of the proposed Quebec and Maritime Provinces excursion of the International Geological Congress.

Mr. W. A. Bell completed his examination of the Joggins section in Nova Scotia, and devoted special attention to the Carboniferous rocks on each side of the Cobequid mountains.

Mr. J. E. Hyde made a special study of the Carboniferous rocks about Sydney, N. S.

Mr. E. R. Faribault continued his mapping of the Goldbearing series in the southern portion of Queens and Lunenburg counties between Vogler Cove and Liverpool. At Fifteenmile brook an occurrence of tungsten ore was found.

Mr. W. J. Wright continued his examination of the eruptive rocks of western Nova Scotia.

TOPOGRAPHICAL DIVISION.

Mr. W. H. Boyd was occupied with the supervision of the field work being carried on by his division.

Mr. D. A. Nichols mapped in detail the mining areas on Texada island.

Mr. W. E. Lawson began a topographic survey of the Lillooet district.

Mr. K. G. Chipman was engaged in topographical mapping in the Windermere district.

Mr. B. R. MacKay completed the topographical map of the Blairmore district.

Mr. S. C. McLean triangulated the Flathead district.

Mr. A. C. T. Sheppard made a topographical survey of the district about St. John, N. B.

BIOLOGICAL DIVISION.

Mr. J. Macoun continued his study of the flora of Vancouver island.

Mr. J. M. Macoun spent a portion of the season in botanical work on the southern end of Vancouver island, and the remainder in the study of the flora and fauna of Strathcona Park.

Mr. P. A. Taverner made some zoological collections in the neighbourhood of Ottawa, as did also Mr. C. A. Young.

ANTHROPOLOGICAL DIVISION.

Ethnological.

Mr. E. Sapir, in addition to supervision, did a small amount of collecting.

Mr. C. M. Barbeau continued work among the Wyandotte Indians, of Oklahoma, collecting texts and grammatical information. Songs, photographs, and specimens were collected, and studies in technology were made.

Mr. A. A. Goldenweiser continued work among the Iroquois, securing much text material, songs, and data on social organization and religion.

Mr. F. H. S. Knowles made a study of physical anthropology among the Iroquois near Brantford, taking numerous measurements for the study of the type. Skeletal material was also obtained.

Mr. W. H. Meckling pursued the study of the Malecite Indians of New Brunswick.

Mr. Paul Radin was engaged in work on the Ojibwas of Ontario, especially as regards mythology, language, and social organization.

Mr. V. Stefansson, who spent four years among the Eskimo of the Arctic, between the Mackenzie river and Coronation gulf, returned home in the autumn, with excellent collections.

Mr. J. A. Teit carried on researches among the Tahltan Indians, on Telegraph creek, B.C.

Mr. F. W. Waugh continued studies in technology among the Iroquois on various reserves in Ontario, Quebec, and New York. Specimens and photographs were collected.

Archæology.

Mr. H. I. Smith supervised field work carried on near Prescott by Mr. W. J. Wintemberg. Here a village site was excavated and a great quantity of material obtained for study and exchange. Photographs and notes were secured.

Mr. W. B. Nickerson made a reconnaissance in Manitoba, and secured specimens, photographs, and information regarding sites.

PROGRESS OF DIVISIONS.

Publication Division.—The division of publications was reorganized. Mr. Wyatt Malcolm, Geological Compiler, was given charge of the division, with Mr. A. Young, clerk of correspondence, and Mr. R. Lyons, clerk of publications.

The number of letters received during the year requesting publications was 5,375. The number of publications sent out in response was 20,389, distributed as follows: 17,218 to Canada, 1,890 to the United States, 422 to Great Britain and Ireland, and 859 to foreign countries. In addition, 15,925 publications were distributed amongst various leading libraries, geological and mining societies, etc., throughout Canada and in various parts of the world. The sale of publications amounted to $363.07.

Geological Division.—The growth of the Survey both in the scope and extent of its work, and in personnel, particularly in younger officials, made necessary the detailing of two men from regular field work to assist in general supervision, and to act in consultative and advisory capacity toward the staff. Mr. O. E. LeRoy has

accordingly been made geologist-in-charge of field work, and Mr. G. A. Young geologist-in-charge of office work.

The approaching meeting of the International Geological Congress in Canada has thrown a vast amount of extra work upon the Geological Survey, particularly upon the geological and draughting divisions. The excursions in connexion with the Congress extend from Cape Breton island to Vancouver and Dawson, and cover practically all the main routes of transportation, including the new transcontinental railways. With the exception of those relating to northern Ontario, undertaken by the Department of Mines of Ontario, the preparation of the guide books describing the geology and economic resources of the routes is being done by the Survey. Some idea of the magnitude of this task may be gathered from the fact that this entails the preparation of about 140 special maps, in addition to those already available as ordinary Survey publications. Such convenient and well illustrated booklets on the geology and resources of the main railways and waterways have long been needed, and will prove of great value to all travellers in Canada who desire to secure an intimate knowledge of the country. The material for these guides is being prepared for each district by the geologists who have done the field work in the district under review. Mr. Charles Camsell is acting as general editor.

The coal resources of the world has been selected as the main topic for discussion at the session of the Congress. As the basis of the discussion, a monograph, consisting of three volumes of text, and a large atlas on the coal resources of the world are being edited by the Survey. The proper authorities in each country have been requested to furnish reports on the coal resources of their respective countries, and, in response, excellent reports, many including the results of special new studies, are being received. Mr. W. McInnes is taking general charge of the editing of this monograph.

Topographical Division.—The topographical division is industriously mapping the country, and turning in the completed manuscript of their maps, which are piling up on account of the inadequacy of the present arrangement for reproduction. This should not be. If we were given engravers so that the engraving could be done in the same office as the map-making, much of this trouble would be avoided.

Draughting Division.—The special maps required for the Geological Congress —about 140 in number—put a heavy strain upon the draughting division, and it is greatly to the credit of Mr. Senecal and his staff that they were able to do this work, in addition to the regular work, which could not be postponed. To add to the strain, several of the staff were laid up with typhoid during the heaviest part of the work. I wish to record that the whole staff cheerfully gave up their holidays for the year in order to see the work through. The preparation of the Congress special maps was placed in the hands of Mr. A. Dickison, and a small staff of draughtsmen assigned to him. By careful designing and untiring industry, he has assured the successful completion of this great task.

Photographic Division.—Some progress was made in furnishing and equipping the photographic laboratory, with resulting increase in the usefulness and efficiency of this division. Photography is now being used with advantage in almost every branch of the work of the Survey, though, of course, it is in connexion with map work that its greatest usefulness is found.

During the past year the following work was turned out by this division:

Contact prints	8,333
Bromide enlargements	785
Exposures developed	2,773
Dry-plate negatives made	424
Wet-plate negatives made	376
Blue prints	74
Photostat prints	186
Lantern slides made	156

Library.—The death of Mrs. Alexander, for many years librarian, has seriously affected the work of the library, and temporarily put a stop to cataloguing. Arrangements have been made to house the library of the Royal Society in the gallery of the Survey library. This will be mutually advantageous, as it will give the staff access to works not found in our scientific library.

Museum.—Some progress has been made in connexion with the Natural History Museum, though seriously handicapped by the lack of properly equipped workrooms, and storage rooms, which are now an absolute necessity. Moreover, valuable collections are being seriously impaired on account of lack of means whereby to preserve them. Cases for the Anthropological Hall were received, and are now being set up. Collections to fill this hall are ready for installation.

Mr. Taverner has designed and made considerable progress on the specimens for a case illustrating, in the best modern manner, the habitat and habits of the birds of the Atlantic coast. The model of the case and a number of the prepared specimens have been placed in a temporary exhibit.

Little could be done in the Mineralogy Hall, as the position of Assistant Curator has been left vacant and the time of the Curator is taken up with other duties: the cases have, however, been filled with a temporary exhibit.

The Vertebrate Palæontological Hall has been opened with a temporary exhibit pending the installation of permanent cases.

While the progress in the way of permanent exhibits in the public halls leaves much to be desired, excellent results are to be reported in the acquisition of specimens for the Museum. The anthropological collections are becoming widely representative of the native races of Canada, and valuable additions have been made to the biological collections.

A magnificent donation of Canadian birds was received, presented by Mr. J. M. Fleming, of 267 Rusholm road, Toronto. The collection includes about 350 specimens, most of them mounted, but some skins and some mammals are included. The workmanship upon the mounted birds is especially good, some of the specimens being second to none in the world. Included in the collection are many rare species and type specimens.

It is particularly gratifying to receive such a valuable gift from a private individual, for it is through the interest and beneficence of public-spirited citizens, only, that a national museum can attain greatness and importance. As evidencing this practical interest in our Canadian institution, this gift is valuable, apart from its intrinsic worth.

A commendable feature in connexion with this gift is that it is made without conditions, so that for all time the Curators will be free to make the most valuable use possible of the material. No matter how innocent or wise restrictions accompanying a gift may appear to be, in the course of time, under changing conditions, the restrictions may not only prevent the gift from being longer of use, but may make it a positive detriment to the Museum.

Mr. Fleming, with his knowledge of museums and museum work, has made no such mistake.

Perhaps the most notable addition to the collections, at all events the most striking, have been the dinosaurs collected during the past season by Mr. Chas. H. Sternberg, perhaps the best known collector in the world, whose specimens are to be found in all the great museums.

The services of Mr. Sternberg, and his son Charles, have been secured, and he was sent on a well-equipped expedition to collect vertebrate remains from the rich bone beds discovered by the Geological Survey twenty-five years ago, in the Red Deer river, Alberta. This expedition was fortunate enough to discover two complete specimens of the large duckbilled dinosaur. A well-equipped vertebrate palæontological laboratory has been installed and in it one of the specimens, 32 feet long, is being mounted by Mr. Sternberg and his son, as a panel mount, the other, about 40 feet long, will be set up as an open mount.

A museum committee was formed, consisting of the officials of the Survey having to do with the Museum, for the purpose of considering matters connected with the Museum. From this committee, a small executive committee was selected, consisting of Mr. R. A. A. Johnston, secretary, and Messrs. H. I. Smith and L. M. Lambe, to look after executive details and make recommendations for the consideration of the General Committee and the Director.

Much time is being spent on the permanent exhibits, which will be of the best and most modern type, and the Museum, when these exhibits are installed, will be of great educational value, as well as interesting.

GEOLOGICAL DIVISION.

GEOLOGY OF A PORTION OF THE YUKON-ALASKA BOUNDARY, BETWEEN PORCUPINE AND YUKON RIVERS.

(*D. D. Cairnes*)

Introduction.

The field season of 1912 was devoted to studying and mapping the geology along portions of the Yukon-Alaska boundary between Porcupine and Yukon rivers. This work, commenced in 1911, was in continuance of the joint undertaking of the Geological Surveys of the United States and Canada to make a geological examination of the country along the 141st meridian (the International Boundary) from the Yukon river to the Arctic ocean. The work to the north of the Porcupine river was undertaken by the United States Geological Survey, and that to the south of the Porcupine by the Canadian Geological Survey; a commencement was made in 1911 and the undertaking was completed in 1912. Mr. A. G. Maddren[1] and the writer[2] having had charge of the portions of this work performed respectively by the United States and Canadian Governments.

During both seasons, the writer accompanied the Boundary Survey parties to the field and, in this way, special travelling facilities were obtained. Topographic sheets were furnished by the International Boundary Survey, which greatly facilitated the geological work. The writer desires to express his indebtedness to the various members of the International Boundary Survey, especially to Messrs. J. D. Craig and Thos. Riggs, who had charge respectively of the Canadian and United States parties.

During 1912, Messrs. F. J. Barlow, S. E. Slipper, and W. S. McCann were attached to the writer's party, as field assistants. All of these discharged their duties in a highly satisfactory and capable manner.

During the preceding summer of 1911, the geology along the boundary line south of Porcupine river was mapped from Orange creek, at latitude 66° 10′, north to latitude 67° 00′, a distance of about 58 miles. In 1912, work was commenced at Porcupine river, latitude 67° 25′ and carried south a distance of 29·8 miles to latitude 67° 00′, where mapping had been discontinued at the close of the previous season. Camp was then moved southward to Orange creek and from there the work continued south to the Yukon river, a distance of 104 miles.

Previous Work.

No geological work has been performed along the 141st meridian between the Porcupine and the Yukon except in the immediate vicinity of these rivers. McConnell came down Porcupine river in 1888, making a geological reconnaissance

[1] Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U.S. Geol. Surv., Bull. 520, 1912.

[2] Cairnes, D. D., Geology of a portion of the Yukon-Alaska boundary between Porcupine and Yukon rivers: Geol. Surv., Can., Summ. Rept., 1911, pp. 17–33.

en route[1], and Kindle made a geological examination of the rock formations along the Porcupine below New Rampart House for the United States Geological Survey during the summer of 1907[2]. In addition, a number of geologists, including McConnell[3], Spurr[4], Prindle[5], Brooks and Kindle[6], and others, have reported on the geological formations along Yukon river in the vicinity of the International Boundary. With this exception, practically nothing was known geologically concerning the area in which the writer was engaged during the summers of 1911 and 1912.

Summary and Conclusions.

Topographically, the area or belt along the 141st meridian between Yukon and Porcupine rivers lies for the greater part, at least, within the Yukon plateau province; and since this physiographic terrane in the vicinity of the 141st meridian has a general westerly trend, it is cross-cut by the meridian practically at right angles. Thus, in going from New Rampart House, on the Porcupine, south to Yukon river, the line of travel is transverse to the trend of the main topographic features of the district, and consequently a considerable diversity of topography is encountered.

In certain localities where the prevailing bedrock is limestone or dolomite, the plateau characteristics are still well preserved, and extensive tracts of upland occur having elevations of 3,000 feet or more above sea-level. With the exception of these areas, the original plateau surface has been almost or entirely destroyed and, throughout the greater part of the district, the land surface has become thoroughly dissected.

Two ranges, or mountain groups, are crossed by the boundary line, which have summits rising to elevations exceeding 5,000 feet above sea-level, and it is possible that one or both of these may be connected with the Rocky Mountain system to the west, and thus constitute outlying lobes of that physiographic terrane. It is more probable, however, that these are but isolated mountainous areas included within the Yukon plateau. To the north and south of these more rugged and mountainous areas, as well as between them, the topography consists dominantly of well rounded, irregularly distributed hills, and at frequent intervals throughout the district, westerly-flowing streams are encountered which have in most places deep, steep-walled valleys, the floors of which are as much as 5 miles in width, and from 900 to 1,200 feet in elevation above the sea. Nowhere was any evidence of glaciation noted.

The geological formations are dominantly of sedimentary origin, and range from Recent to Cambrian and probably to Pre-Cambrian in age. The district is of particular interest and stratigraphic importance, however, owing to the fact that all the Palæozoic systems from the Cambrian to the Carboniferous are represented, and perhaps nowhere else in the entire Rocky Mountain region of Canada and the United States is a more complete section of the Palæozoic known within so limited an area. Occasional dykes and relatively small intrusive bodies intersect the Palæozoic and Mesozoic rocks, and intrusive greenstones and, in

[1] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie basins, N.W.T.: Geol. and Nat. Hist. Surv. of Can., Ann. Rept., vol. IV, 1888-89, part D, pp. 129–134.

[2] Kindle, E. M., Geologic reconnaissance of the Porcupine valley, Alaska: Bull., Geol. Soc. Amer., vol. XIX, 1908, pp. 310–338.

[3] Op. cit., pp. 134D–143D.

[4] Spurr, J. E., Geology of the Yukon Gold district, Alaska: U.S. Geol. Surv., 18th Ann. Rept., part III, 1896–97, pp. 89–292.

[5] Prindle, L. M., The gold placers of the Forty-mile, Birch Creek, and Fairbanks regions, Alaska: U.S. Geol. Surv., Bull. No. 251, 1905.

[6] Brooks, Alfred H., and Kindle, E. M., Palæozoic and associated rocks of the Upper Yukon, Alaska: Bull. Geol. Soc. Amer., vol. XIX, 1908, pp. 255–314.

places, highly altered igneous rocks of various types, have an extensive development in association with the Pre-Middle Cambrian terranes.

What are considered to be the oldest rocks in the district are the members of the Yukon group, which are developed only in the vicinity of Yukon river. These are probably of Pre-Cambrian age, and are mainly quartzite schists, schistose amphibolites and mica schists, but include also occasional beds of limestone. Another group of rocks, the Tindir group, which is possibly also of Pre-Cambrian, and is at least of Pre-Middle Cambrian age, is somewhat extensively developed, mainly in two localities, viz., along Porcupine river to the north, and between Ettrain and Harrington creeks, 150 miles farther south. This group of rocks is composed mainly of dolomites, quartzites, shales, sandstones, and associated greenstones, and is thought to be younger than the members of the Yukon group. The members of the Tindir group are overlain unconformably by a thick series of limestones and dolomites, which are dominantly very siliceous in character, and range in age from Middle or Lower Cambrian to lower Devonian. In the northern portion of the district, these rocks are directly overlain by the Racquet series which consists dominantly of white to greyish, heavy bedded limestones containing in places some intercalated cherts and cherty conglomerates. Toward the south, however, the Devonian limestones are overlain by several hundred feet of dark grey to black, thinly-bedded shales and cherts of upper Devonian age, which are in turn followed by 500 to 1,000 feet of thinly-bedded limestones and shales of Mississippian age. More recent than these beds is a thick series of conglomerates, sandstones, and shales comprising the Nation River formation which is thought to be of Pennsylvanian age. The Carboniferous limestones and included cherts in the northern portion of the district, contain both Mississippian and Pennsylvanian fossils, and appear to correspond stratigraphically to the combined beds of the Nation River formation and the underlying Carboniferous limestones and shales; and in the vicinity of Ettrain creek at about latitude 65° 25′ what appears to be a transition from the dominantly calcareous members of the Racquet series, to the more arenaceous and argillaceous sediments of the southern portion of the district, was noted. Just north of Tatonduk river on the extreme western edge of the area mapped, some peculiar reddish conglomerates occur, which appear to have an extensive development to the west. These overlie Devonian limestones, and appear to be either fossil glacial till or consolidated slide material.

The most extensively developed formation in the district is the Orange group, which includes conglomerates, sandstones, shales, slates, phyllites, and quartzites, of Mesozoic and probably chiefly of Cretaceous age. These extend to within about 50 miles of the Yukon, and from there north for over 90 miles are the most prominent rocks in the district. Throughout this distance, occasional beds of a reddish to brownish, rough weathering dolomite occur, which appear to be associated with the beds of the Orange group, but may underlie them.

Overlying all these consolidated rock formations are the superficial deposits consisting of gravels, sands, clays, muck, peat, soil, and ground-ice.

Iron-containing minerals, chiefly hematite, magnetite, and their oxidation products, comprise a considerable percentage of certain beds occurring in the southern part of the district, and portions of some of these deposits contain up to 30 per cent, or even possibly 40 per cent, metallic iron. On Tatonduk river, a few coal seams not, however, exceeding 2 inches in thickness, were noted in Carboniferous shales. In addition, marble, lithographic limestone, and magnesite are somewhat extensively developed in certain localities. The above mentioned constitute, so far as is known, the principal mineral resources of the district, but owing to the remoteness of their occurrence, even these are of no present economic importance.

A GEOLOGICAL RECONNAISSANCE ON GRAHAM ISLAND, QUEEN CHARLOTTE GROUP, B.C.

(*Charles H. Clapp*).

Introduction.

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

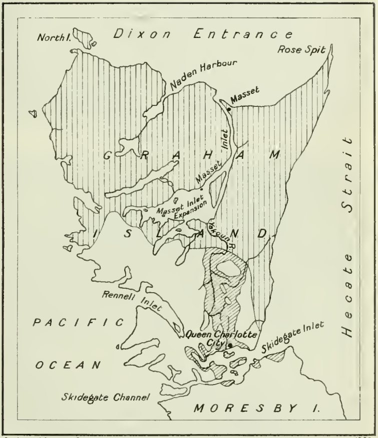
In response to a request to the Director of the Geological Survey from one of the companies prospecting for coal on Graham island, B.C., for assistance in interpreting the results of the prospecting, the writer made a short reconnaissance across Graham island during the field season of 1912. The reconnaissance lasted only seventeen days, from July 29 to August 14, inclusive. The first three days were spent in the vicinity of Skidegate inlet, at the south end of the island. The next eleven days were spent on the reconnaissance across the island from the mouth of the Honna river to the mouth of the Yakoun river, near the east end of Masset Inlet expansion. Most of the travel was by foot, chiefly over trails, but the last part of the trip was made by canoeing from Camp Wilson down the Yakoun river to its mouth. Of the places visited, the best known are: Camp Robertson, Yakoun lake, Camp Wilson, and the camps of the Graham Island Coal and Timber Syndicate, and of the Graham Island Collieries Company. Two days were spent examining, from a launch, the shores of Masset Inlet expansion. On the last day, the shores of the outer and narrow part of Masset inlet were examined, and a trip on foot was made from the town of Masset across to the north beach, and east along the beach to Skonun point.

During the reconnaissance, the writer was assisted by Mr. P. T. Williams, temporary engineer for the Graham Island Coal and Timber Syndicate, and during the first part of the reconnaissance was accompanied by Mr. F. C. Greene, General Manager of the Graham Island Coal and Timber Syndicate. Through the courtesy of Mr. Greene, most of the camp equipment, provisions, means of travel, and labour were furnished. The writer was assisted and given information by the British Pacific Coal Company, Graham Island Collieries Company, American-Canadian Coal Company, and British Pacific Oilfields Company. Particular acknowledgment is due to Mr. Alexander Faulds, engineer-in-charge of development, for the British Pacific Coal Company, at the time of the writer's examination.

The larger part of the area examined is underlain by a series of conglomerates, sandstones, and shales, the Queen Charlotte series, which in places contain coal. It was desired not only to give information to those prospecting for coal on the island, but also to gather the results of recent development and prospecting for coal and oil. It was found that the geology is more complicated, and that the coal basins are smaller and more deformed than has been previously thought. The following report is necessarily incomplete and some of the statements are tentative, but since it will probably be some time before the results of the more complete work planned for the future are ready for publication, it seems best to summarize briefly our present knowledge of Graham island.

AREA AND MEANS OF ACCESS.

Graham island is the largest and, with the exception of North island, a small island off its north coast, the northernmost of the Queen Charlotte group. Its total area is almost 2,500 square miles. The area covered by the reconnaissance is a strip running north and south through the central part of the island, about 50 miles long, varying in width from 1 to 20 miles, and about 300 square miles in area.



Geological Survey, Canada 1296

Diagram showing the geology of
Graham Island, Queen Charlotte Islands, British Columbia.

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Legend

Chiefly Tertiary volcanics with fairly large areas of Tertiary sediments, small areas of Queen Charlotte sediments, and possibly some small areas of granitic rocks, and metamorphic rocks of the Vancouver group.

Queen Charlotte series. (Cretaceous)

Chiefly metamorphic rocks of the Vancouver group and intrusive granitic rocks, with small areas of Queen Charlotte sediments and dykes and "caps" of Tertiary volcanics and intrusives.

To accompany Summary Report by C. H. Clapp, 1912.

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Regular communication with Prince Rupert, the western terminus of the Grand Trunk Pacific railway, is made by steamer which calls at Graham Island ports twice a week, one trip being made to the northern ports, Masset and Naden harbours, and the other to the southern port, Queen Charlotte city on Skidegate inlet, and to the ports on Moresby island. Access to the interior of the island is had by a fairly good trail, over part of which horses may be taken, extending from Skidegate inlet to Camp Wilson, and from there to Masset Inlet expansion. Branch trails lead to Camp Robertson and Yakoun lake, and to the east coast. Masset inlet gives ready access to the centre of the island, and Skidegate inlet affords a complete section across the island. The Yakoun river is navigable with canoes and small shallow-draught boats to Camp Wilson, but above Camp Wilson log jams are seemingly continuous. On account of the thick mantle of superficial deposits and the heavy vegetation, the outcrops are few, and the best exposures are to be found in the creek beds and along the shores of the lakes and inlets.

PREVIOUS WORK.

The early explorations (between 1774 and 1866) to Queen Charlotte islands[1]—under Spanish, British, and American commanders, were purely exploratory and geographic. The first geological examination of importance was made in 1872 by Mr. James Richardson of the Geological Survey. He made a two weeks' examination of the sedimentary measures of Skidegate inlet, which contain anthracite coal seams in the western part of the inlet near Cowgitz. The results of his examination are given in the Report of Progress 1872–73, pages 56–63 and 66–75. In 1878, Dr. G. M. Dawson spent two and a half months examining the eastern and northern coasts of the Queen Charlotte islands, and the shores of Masset inlet. The report of his expedition, published in the Report of Progress 1878–79, pages 1B–239B, is the most valuable of the published contributions to the geology of the islands. In 1895 and 1897, Dr. C. F. Newcomb, of Victoria, made extensive collections of fossils from the sedimentary rocks of Skidegate and Cumshewa inlets, which were determined and described by Dr. J. F. Whiteaves of the Geological Survey. In 1905, Dr. R. W. Ells of the Geological Survey made a reconnaissance survey of Graham island. An examination of the shore-line was made from a sail boat, and a traverse was made across the island from Masset inlet to Skidegate inlet, via the Yakoun river and the trails to Camp Wilson and to Camp Robertson. The results of the reconnaissance are published in Vol. XVI, 1904, of the 'New Series;' pages 1B–46B, 1906. The report is accompanied by two large scale geological maps which, by their appearance, seem to imply that the work was of a detailed nature, whereas it was based merely upon a reconnaissance. Numerous other private examinations have been made, both favourable and unfavourable, as regards the coal deposits of Graham island. Unfortunately, as a rule, only those which are extravagant and unreliable have been made semi-public.

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Summary and Conclusions.

GENERAL GEOLOGY.

The area covered by the writer's reconnaissance on Graham island is largely underlain by a series, called the Queen Charlotte series, of sandstones, shales, and conglomerates, that in places, fairly near the base, contain coal seams. The series rests unconformably upon a surface of considerable relief of metamorphic volcanic and sedimentary rocks, belonging to the Vancouver group and presumably of Jurassic and Triassic age, and on granitic rocks, intrusive into the Vancouver group and correlated with the Coast Range batholith, probably of upper Jurassic age. The Queen Charlotte series is subdivided on a lithological and stratigraphic basis into four members. These differ somewhat from the subdivisions previously made by Dawson, since he includes in the series, rocks which appear to be unconformably below those forming the greater part of the series. The series is of sedimentary origin, and was apparently deposited in a wide valley between highlands of the metamorphic and granitic rocks. In the valley itself, there appear to have been three or four large monadnocks, which remained above the depositional level during the formation of, at least, the lower members of the series, including the coal seams. The date of deposition is generally considered to be Lower to Upper Cretaceous. The series has been greatly deformed, and while it has a general synclinal structure with the longer axis trending north

and south, there are a great many small folds, which, near the crystalline rocks, are closed, and even overturned. The series is also broken by a number of rather small faults.

Breaking through the Queen Charlotte series and forming sills, dykes, and probably laccoliths, and also flows, are igneous rocks, ranging from dacites to basalts. They are doubtless largely of Tertiary age, although possibly erupted at widely separated intervals, and are called the Tertiary volcanics and intrusives. The dacites and andesites occur as dykes and sills up to 50 feet in width, intrusive into the lower part of the Queen Charlotte series. In some places the sills follow the complex folding of the Queen Charlotte series and, in other places, the dykes cut sharply across the deformed rocks of the series. In the northern part of Graham island, the basalts which underlie the greater portion were evidently formed on the surface as flows and ash or other fragmental rocks. They are now warped into rather broad open folds. In places, these flows are involved with sedimentary rocks of Tertiary age; and at Tow hill, on the north shore of Graham island, they apparently rest upon a denuded surface of the Tertiary sediments. In the central part of Graham island the basalts apparently form intrusive masses, presumably laccoliths, and possibly flows, and now occur capping the large monadnocks which surmount the basin underlain by the Queen Charlotte series.

The Tertiary sediments are exposed at widely separated localities in northeastern Graham island, and probably occur in separate basins, some of which may be fairly large. The sediments consist of partially consolidated to consolidated sandstones, clay shales, and conglomerates, with numerous beds of lignite, which in places are fairly thick. The sediments are in part at least of marine origin and of Pliocene or late Miocene age. They are moderately to slightly deformed and, as mentioned, are in places involved with the Tertiary basalts.

All of the rocks have been greatly denuded, especially the less resistant sediments of the Queen Charlotte series and the slightly deformed Tertiary volcanics and sedimentary rocks. The former now underlie a lowland in the central part of Graham island, bordered by highlands of the metamorphic and granitic rocks, and surmounted by three or four large monadnocks composed of the metamorphic and Tertiary volcanics. The latter now underlie a broad, flat lowland that forms the northeastern and northern parts of Graham island.

During the Glacial period the western highland, the Queen Charlotte range, was covered by an ice cap, and valley glaciers filled and scoured out the larger valleys forming fiords and lake basins. Also, the northeastern lowland was apparently covered by piedmont glaciers, since it is now covered in places with glacial till. It is, however, covered by a more extensive deposit of stratified clays, sands, and gravels of marine origin and of interglacial or post-Glacial age.

ECONOMIC GEOLOGY.

The mineral resources of the area examined are virtually confined to coal, possibly oil, and clay. Coal is found at a fairly definite horizon, in one of the lower members, the Haida member, of the Queen Charlotte series, which is presumably of Cretaceous age, and in the Tertiary sediments. The Cretaceous coals range from a semi-anthracite to a low carbon bituminous, this variation apparently corresponding to a variation in local deformation and igneous intrusion. The Tertiary coals are lignites, most of them brown, with a woody or fibrous structure, although some are black, with an irregular coaly structure and conchoidal fracture.

The Cretaceous coals have been found at several places, the more important of which are: Cowgitz and vicinity, Camps Robertson and Anthracite, and Camp Wilson. Cowgitz and Camps Robertson and Anthracite occur on the western

limb of the large synclinal basin underlain by the Queen Charlotte series. At these localities the coal, which ranges from a semi-anthracite to a rather high carbon bituminous, is rather high in ash and in places is crushed, the associated measures having been greatly deformed and cut by the Tertiary intrusives. Camp Wilson is a small, detached, synclinal basin fringing the west flank of the largest of the monadnocks which surmount the basin underlain by the Queen Charlotte series. The coal here is a good quality, low carbon, bituminous coal, and is not crushed, although the measures are considerably deformed. They are not, however, cut by Tertiary intrusives in the immediate vicinity of Camp Wilson.

Development work has been done in these areas, and prospecting is still being carried on. As yet, there has been no commercial production. What might be called the actual coal reserve, or the coal reserve of a high degree of probability, is very small, about 6,900,000 tons. The probable or possible reserve is, however, much greater, since it is fairly probable that the coal exposed in the west limb of the large syncline extends below the syncline and may be found in the east limb, and hence the prospecting of this limb is strongly recommended. One or two of the smaller detached basins are probably more extensive than they are known to be at present, and the location of their extension by prospecting is also recommended. The coal reserve of a fair degree of probability may be conservatively estimated as about 293,000,000 long tons.

The Tertiary coals or lignites are confined to the northeastern part of Graham island. Lignite is known to occur at several localities, the best known of which is Skonun point on the north shore. Here, at low tide, there are exposed more than ten seams, of varying persistency and up to 15 feet in thickness, of a tough woody lignite. The actual lignite reserve at Skonun point is conservatively estimated as 60,000,000 long tons, but the probable lignite reserve of Graham island is at least 1,000,000,000 long tons. The quality of the lignite is fair, since the ash is low, and since the lignite is strong and does not slack on exposure.

Prospecting for oil has been carried on for some years, in small areas of bituminous shales, involved with Tertiary basalts, that occur in the western part of Graham island, in particular along the west coast between Tian point and Frederick island. As yet, the prospecting has been carried on without success.

Graham island abounds in clays and shale-clays suitable for common brick and other products made from low grade clays, and it is possible that some of the shale-clays are of fairly high grade. Shale-clays are found in the lower member of the Queen Charlotte series and in the Tertiary sediments, although those found in the Tertiary sediments are but slightly indurated. Thick and very extensive beds of clay occur also in the northeastern part of Graham island in the stratified superficial deposits.

General Character of the District.

TOPOGRAPHY.

Regional.—The Queen Charlotte group, of which Graham island is the largest and virtually the northernmost island, constitutes the northern range of the Vancouver system, which is separated from the Coast Range of the mainland of British Columbia by the submerged northern portion of the Pacific Coast downfold. The Queen Charlotte range trends N. 28° W., is almost 180 miles long, and averages about 20 miles in width. That portion of the submerged downfold separating the range from the mainland is from 30 to 100 miles wide, and is called Hecate strait. The range, which is largely composed of resistant metamorphic and crystalline rocks, is rugged, with steep, although smoothed, glaciated slopes, and rounded, and rarely serrated summits. Some of the

mountains, especially those of the northern part of the range, are flat-topped and mesa-like, while the upper portions of others are cuesta-like, with a steep slope on one side and a comparatively gentle slope on the other. These features suggest that some of the metamorphic and crystalline rocks are capped with more recent, only slightly deformed rocks, doubtless younger lavas. The summits vary from 3,000 to about 5,000 feet above sea-level. The range has evidently been glaciated and the valley glaciers, descending to the east and west, scoured out many of the larger valleys, converting them into fiords and lake basins. One of these fiords, Skidegate channel, which widens to the east into Skidegate inlet, crosses the range between the two largest islands of the group, Moresby island to the south and Graham island to the north.

Northeast of the range and in the range, are low areas underlain by sedimentary and volcanic rocks, which in general are less deformed and less resistant than the older rocks. The largest of these low areas is the northeastern portion of Graham island, which in its northern part is nearly 60 miles wide. Most of this lowland, the northeastern part of which is formed of flat-lying unconsolidated sediments that have apparently been recently uplifted a few hundred feet above sea-level, is very flat, only from 100 to 200 feet above sea-level. The lowland is surmounted by only a few, conspicuous, flat-topped mesas, with summits 500 to 800 feet above sea-level, composed of the younger volcanic rocks.

Local.—The area which was covered by the writer's reconnaissance on Graham island, includes portions representative of all the physiographic provinces of the island. That portion underlain by the deformed rocks of the Queen Charlotte series, in which the greater part of the reconnaissance was carried on, is a relatively low basin with a north-south elongation, between ranges of the more resistant crystalline rocks. The basin is widest in its southern part, where it is about 20 miles wide. Extending from the main basin for several miles, are a few narrow, elongated basins between ridges of crystalline rocks. These basins and the main basin are occupied by the largest streams of the area and portions are below sea-level, forming Skidegate inlet. North of Skidegate inlet the basin, drained by the southward-flowing Honna river, narrows to about 3 miles. Still farther north, about 6 miles from Skidegate inlet, it widens to about 6 miles. This portion is about 15 miles long, and is drained chiefly by the northward-flowing Yakoun river and its tributaries. Its central and eastern portions are, however, drained by small streams, which cross the low range that confines the basin on the east, and then cross the eastern lowland to the coast. The Yakoun river has its source in Yakoun lake, a small glacial lake about 4 miles long, whose southern end extends into the Queen Charlotte range. The river has a general northward flow, although its course is meandering, and follows for the greater part the western boundary of the basin. Its tributaries have cut narrow gorges in the sedimentary rocks, and the river itself flows in a rather narrow valley, although its grade is gentle. In the central and northern portions of the basin, whose average elevation is from 300 to 900 feet above sea-level, the sedimentary rocks are surmounted by three or four monadnocks of resistant volcanic rocks. The largest of these in the northern part of the basin, east of Camp Wilson, attains an elevation of 2,100 feet, and is nearly 20 square miles in area.

To the northeast, the basin merges into the broad flat of the northeastern part of Graham island. The lower portion of the Yakoun river meanders across the southwestern part of this lowland, in places between cut banks, and empties into Masset Inlet expansion at its southeastern angle. The southern and western parts of Masset Inlet expansion are fiord-like in character and penetrate into the heart of the Queen Charlotte range, which in its northern portion is comparatively low, 1,000 to 2,000 feet in height, with many of the flat-topped and cuesta-

like summits already mentioned. The shores of the northeastern and eastern parts of Masset Inlet expansion and of the long, narrow channel extending to the north coast, are low, bordering the northeastern lowland of Graham island. The north coast of Graham island is low and in general fairly straight. The superficial deposits of the lowland have been retrograded and the retrograded material has been distributed along the shore, forming barrier beaches, such as that which protects Masset harbour, and spits, such as the long and dangerous Rose spit, the northeastern point of Graham island. The hard, straight beach, probably the finest in Canada, is broken in its eastern portion only by three small rounded points of hard rocks. Farther west are Masset and Naden harbours, apparently drowned valleys.

CLIMATE AND VEGETATION.

The climate of Graham island is uniform and rather cool, the average temperature being about 35° F. during the winter months and 55° F. during the summer months. The rainfall is excessive, from 80 to 120 inches.

The island is heavily forested, chiefly with conifers—spruce, hemlock, and yellow cedar predominating. The forest differs from that of Vancouver island in the predominance of yellow cedar and in the absence of Douglas fir. The undergrowth is heavy and is characteristic of the North Pacific coast, being composed chiefly of salmonberry, huckleberry, and sallal. Although there are no wide stretches of open country, there are, not only in the northeastern lowland of Graham island, but also in the central basin underlain by the Cretaceous sediments, fairly extensive areas of swampy meadow or muskeg, which support a heavy growth of coarse grass and broad-leafed plants, but only a very scanty growth of scrub spruce or hemlock. The occurrence of muskeg on fairly steep slopes is peculiar, and is to be accounted for by the thick layer of alluvium and humus and by the moist, cool climate. As yet there is very little farming or agriculture, but it seems probable that a large part of the northeastern lowland of Graham island, if cleared and drained, will be suitable for agriculture and grazing, as well as large areas in the central basin and in the larger valleys of the mountainous region.

General Geology.

Table of Formations.

Superficial deposits	Pleistocene and Recent.
Tertiary sediments	Upper Miocene or Pliocene.
Tertiary volcanics and intrusives Dacites, andesites, and basalts	Upper Miocene or Pliocene and probably Eocene.
Queen Charlotte series Skidegate sandstones. Honna conglomerate. Haida sandstones and shales. Image (basal) conglomerates. (May include contemporaneous volcanics).	Middle or upper Jurassic or lower Cretaceous, and probable middle and upper Cretaceous.
Batholithic intrusives Granodiorite, diorite, etc.	Upper Jurassic.
Vancouver group Argillites, slaty shales. Metamorphic volcanics, andesites, and basalts.	Triassic and Jurassic.

GENERAL DESCRIPTION OF FORMATIONS.

Vancouver Group.

The rocks upon which the Queen Charlotte sediments rest unconformably, consist chiefly of metamorphic, rather basic volcanics with some crystalline limestones and argillites and sandstones, all of Triassic and, presumably, Jurassic age, and are members of the Vancouver group.[1] They surround the basin of the Queen Charlotte sediments and may form at least the lower part of the three or four monadnocks which surmount the basin. In the southern part of Graham island they are the principal rock group of the Queen Charlotte range.

Metamorphic Volcanics.—The metamorphic volcanics, with which are associated the small lentils of crystalline limestone, are the principal formation of the Vancouver group. They are similar to those of Vancouver island and consist of meta-basalts and meta-andesites. They are dark purplish to green-coloured rocks, with a very fine grained or aphanitic and in some instances amygdaloidal groundmass, with or without small to medium sized phenocrysts of feldspar and of altered dark minerals. They consist essentially of plagioclase feldspar, varying from labradorite to andesine, and originally augite and hornblende, although these last are usually completely altered. Magnetite is virtually always present as an accessory mineral, and in some varieties olivine seems to have been present. The rocks are moderately to greatly altered, chlorite, serpentine, epidote, calcite, and sericite being the chief secondary products. Pyrite also is common, occurring in rather small disseminated grains. Besides the normal flow and injected types, many fragmental varieties occur, ranging from fine tuffs and breccias to coarse agglomerates. The volcanics are greatly fractured and sheared and frequently mineralized to a greater or less extent along shear zones. As stated, these rocks are unconformably overlain by the Queen Charlotte series, and pebbles of them are found in the basal conglomerate and in the conglomerates of the Haida member. Pebbles of them are found sparingly in the Honna conglomerate.

Argillites and Sandstones.—The argillites and sandstones are similar to the Sicker series of Vancouver island.[2] They are found on the south shore of Maude island in Skidegate inlet and Dawson[3] maps them on the south shore of Skidegate inlet on Moresby island. They are also found west of the Queen Charlotte series basin to the north of Yakoun lake, and are well exposed on the west fork of Yakoun river. The rocks consist of dark coloured, carbonaceous, laminated argillites and thin-bedded, siliceous, fine to coarse grained sandstones, and are locally called 'ribbon rocks.' The rocks are considerably metamorphosed, more so than the slaty rocks of the Queen Charlotte series, and are cut by quartz and calcite veinlets. They are folded and contorted, and fractured and faulted. The general axis of deformation seems to be about N. 25° W., corresponding in trend with the Queen Charlotte range, but there are many small transverse folds and faults. These rocks are unconformably overlain by the sediments of the Queen Charlotte series and fragments of them occur in the basal conglomerates and in the higher conglomerates as well. The argillites and sandstones are clearly of sedimentary origin. The argillites on the south shore of Maude island contain abundant specimens of a

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[1] Dawson, G. M., Ann. Rept., 1886, Geol. Surv. of Can., p. 10B. Clapp, C. H., Memoir No. 13, Geol. Surv., Can., p. 44.

[2] Clapp, C. H., Memoir No. 13, Geol. Surv., Can., p. 71.

[3] Dawson, G. M., Rept. Progress, 1878–79, Geol. Surv. of Can., map facing p. 63B.

species, which, as stated by J. D. Burling, assistant invertebrate palæontologist of the Geological Survey, is comparable with *Astarte carlottensis*, Whiteaves, found by Dawson at the east end of Maude island, and considered by him to come from the 'lower shales' (Haida member) of the Queen Charlotte series, which member is considered by Whiteaves to be Lower Cretaceous. However, the species 'affords no satisfactory evidence' for placing the argillites in the Cretaceous or pre-Cretaceous; while the field relations of the argillites show that they are unconformably below the Queen Charlotte series, and presumably of Jurassic or Triassic age, in general conformable with the meta-volcanics of the Vancouver group.

Batholithic Intrusives.

Intrusive into the rocks of the Vancouver group and unconformably below the Queen Charlotte series, are granitic rocks, chiefly granodiorites and diorites. These are reported to occur in large masses in the Queen Charlotte range, but were seen by the writer only to the east of Yakoun lake, where there is a small ridge of diorite. Granodiorite is reported to occur also to the east of the basin of Queen Charlotte sediments. These batholithic rocks, fragments of which occur in the Honna conglomerate of the Queen Charlotte series, are similar to the rocks of the Coast Range batholith, and doubtless should be correlated with them, and hence are considered to be of middle or upper Jurassic age.

Queen Charlotte Series.

Resting unconformably on the metamorphic rocks of the Vancouver group and on the granitic rocks intrusive into them, is the thick series of sediments, in one member of which are the coal seams of Graham island. These sediments have been subdivided by Dawson[1] into the following:—

		Thickness.
A.	Upper shales and sandstones	1,500 feet.
B.	Coarse conglomerates	2,000 "
C.	Lower shales and sandstones (with coal)	5,000 "
D.	Agglomerates	3,500 "
E.	Lower sandstones	1,000 "

The name Queen Charlotte Island group was proposed by Whiteaves [2] in 1882 for the three lower subdivisions (C, D, and E), and in 1889 Dawson[3] grouped the three subdivisions together as the Queen Charlotte Island formation. In 1872, Richardson[4] recognized an unconformity at the base of sub-division C, which was his lowest subdivision. Dawson[5] considered this unconformity 'essentially unimportant' and to be expected on account of the dissimilarity of the 'agglomerates' (D) and the 'shales' (C). He also recognized that movements, which accentuate the appearance of unconformity, had taken place between the 'agglomerates' and the 'shales'. Since fossils identical with those occurring in rocks placed by Dawson in subdivision C, occur in beds (subdivision E), which Dawson considered as conformably underlying the 'agglomerates' (D), and since fossils also occur in some parts of the upper portion of the 'agglomerates' (D), Dawson considered that the 'agglomerates' (D) and 'lower sandstones' (E) were conformable with the lower shales (C), and underlay them. Ells,[6] although he does not mention

[1] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., pp. 63B–84B.
[2] Whiteaves, J. F., Trans. Royal Soc., Canada, vol. I, 1882, sec. 4, p. 85.
[3] Dawson, G. M., Am. Jour. Sci., vol. XXXVIII, 1889, pp. 120–127.
[4] Richardson, James, Rept. of Progress, 1872–73, Geol. Surv. of Can., pp. 56–63.
[5] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., pp. 66–67B.
[6] Ells, R. W., Ann. Rept. vol. XVI, 1904, Geol. Surv. of Can., pp. 1–46B, 1906.

Dawson's conclusion as to the nature of the contact between the subdivisions C and D, considers the so-called 'agglomerates' as pre-Cretaceous, and so maps them, and, therefore, considers them as unconformably below the lower shales (C). The writer has seen the 'agglomerates' only at Image point on the north shore of Skidegate inlet near the entrance, and at Steep point near Cowgitz in the western part of Skidegate inlet. At these localities the 'agglomerate' appears to be a basal conglomerate of considerable thickness, resting on metamorphic volcanic rocks, which seem to belong to the Vancouver group and which are unconformably below the sedimentary rocks. Since the overlying sedimentary series are conformable, although they may have a considerable range in age, it seems best to extend the name Queen Charlotte Island, or as it may be conveniently shortened, Queen Charlotte, to embrace not only the 'lower shales' (C) but the entire conformable series of sedimentary rocks which overlie the metamorphic rocks of the Vancouver group and the granitic rocks. This series, called the Queen Charlotte series in this report, may be subdivided for convenience in description as in the table of formations. The members are described separately as to distribution and lithological character, in the order of age, the lowest or oldest member being described first; but as to the structure, origin, and age, the members are described as a unit.

Image Member[1] *(Basal Conglomerate)*.—The Image member is the basal conglomerate of the series. It appears to be developed only locally, the Haida member, in places, resting directly on the crystalline rocks. It is, however, fairly thick in other places, and may have a maximum thickness of 400 or 500 feet. It is typically exposed at Image point at the entrance of Skidegate inlet and at Steep point at the west end of the inlet. It occurs also on Maude island and presumably at the entrance of Alliford bay, on the south shore of Skidegate inlet. In the interior of Graham island the Image conglomerate is not typically developed, the basal conglomerate being very thin and more of the nature of a pebbly or arkose sandstone, which is interbedded with fine-grained slaty sandstones, typical of the Haida member. The typical Image conglomerate is a coarse conglomerate composed of large rounded to subangular fragments of metamorphic andesites and basalts, characteristic of the Vancouver volcanics, in a green sandy matrix composed of detritus of the older volcanic rocks. The basal conglomerates found in the interior of the island are finer grained with a more abundant sandy matrix composed of quartz and feldspar grains with secondary dark coloured minerals, frequently partly cemented and even replaced by calcite. Where the conglomerate overlies the argillites and fine-grained siliceous sandstones, fragments of these, usually angular, occur in the conglomerate.

Haida Member.—The Haida member is the thickest and most extensive of the series, and contains the coal seams. It overlies the Image conglomerate, although as mentioned, in places, notably in the interior of Graham island, it virtually rests directly upon the underlying crystalline rocks. It is well developed on both sides of the sedimentary rock basin at Skidegate inlet, and continues north along both sides of the basin. North of the narrow portion of the basin, east of Yakoun lake, the Haida member is virtually the only one of the series now found. It varies greatly in thickness, from about 1,000 feet to 5,000 feet. The thickest portion occurs along the eastern side of the basin in the vicinity of Skidegate inlet.

The rocks of the Haida member are chiefly thin-bedded, grey to black, carbonaceous and argillaceous, fine-grained sandstones grading to carbonaceous sandy or slaty shales. Toward the base, the rocks are much coarser grained,

[1] J. D. Mackenzie, who spent the summer of 1913 on more detailed work on Graham island, reports that the typical Image conglomerate is conformable with the Vancouver volcanics and the argillitic and slaty shal and unconformable with the Haida formation. This accounts for its absence in the interior of Graham island, and, appears to the writer, to be a correct interpretation.

and composed chiefly of fine conglomerates with well rounded pebbles, pebbly sandstones, and thick- and thin-bedded yellowish grey sandstones, the thin-bedded sandstones predominating. The conglomerates are virtually confined to the base, and at Image point rest on the coarse Image conglomerates, the contact probably being a thrust fault. Above the conglomerates are alternating thin- and thick-bedded sandstones, the former predominating, but the latter, since they are more resistant, forming small cuesta-like ridges. In the sandstones are numerous small, coaly lenses and impressions of trees and branches. Upward the grey, carbonaceous and shaly sandstones, with coaly and carbonaceous slaty shale interbeds, predominate. Inland, north of Skidegate inlet, the rocks tend to grow coarser grained and contain a larger percentage of the undecomposed and unsorted material derived from the mechanical disintegration of the underlying Vancouver metamorphic andesites and basalts. Gritty and pebbly sandstones, with well rounded pebbles of meta-andesite and meta-basalt, with coaly lentils and impressions of tree trunks and branches are common, interbedded with laminated, fine grained to dense, bluish green to black, carbonaceous, and in places concretionary, sandstones. Their cement is both calcareous and ferruginous. Calcite sometimes replaces large portions of the rock, and pyrite is a common secondary mineral. Usually the base consists of a conglomerate with pebbles of the Vancouver volcanics in a predominant sandy matrix, but in places, as east of Camp Wilson, rather typical yellowish brown, arkose sandstones composed of quartz and feldspar are found resting on the volcanic rocks.

Honna Member.—The Honna member consists of a characteristic conglomerate that conformably overlies the Haida member, the junction between the upper sandy shales of the Haida member and the Honna conglomerate being pronounced. The Honna conglomerate is developed on both sides of the basin at Skidegate inlet. The eastern limb is exposed to the west of the Honna river, where the conglomerate forms pronounced cliffs which extend along the shore for a half mile. The conglomerate extends inland for 6 or 7 miles, forming, to the west of the Honna river, a rather conspicuous upland, which steeply surmounts the area underlain by the Haida sandstones and shales. On the west side of the basin the conglomerate is exposed on the shore south of Slate Chuck creek. It also occurs along the southern limb of the basin and is exposed on several islands in Skidegate inlet, the largest being Lina, Maude, and South islands, and along the south and west shores of Skidegate inlet on Moresby and Graham islands, between South bay and the entrance to Long arm. Dawson maps another small area, which must be a basin-shaped syncline to the west of Long arm. The thickness of the Honna member varies from about 1,500 feet to nearly 3,000 feet, being thickest on the east limb of the basin. The average thickness is probably near 2,000 feet as given by Dawson.[1]

The Honna member consists chiefly of a rather coarse conglomerate, with subangular to well rounded pebbles, up to 4 or 5 inches in diameter, in a rather coarse matrix of subangular to sub-rounded quartz and feldspar grains with secondary dark minerals, such as chlorite. The pebbles are predominantly quartzose, chiefly cherts, cherty slates, and quartz-feldspar porphyrites; but granitic rocks, chiefly granodiorite, and metamorphic volcanics are not uncommon. Interbedded with the conglomerates are sandy conglomerates and coarse sandstones, and even some shaly sandstones, while some of the conglomerates have only very little sandy matrix. In the upper part of the member is a zone, a few hundred feet in thickness, of thin-bedded and shaly sandstones interbedded with conglomerates, which is the transition into the Skidegate member, which is composed largely of sandstones.

[1] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., p. 65B.

Skidegate Member.—The Skidegate member is the uppermost of the Queen Charlotte series, and occupies the central portion of the sedimentary rock basin. It extends along the north shore of Skidegate inlet for about 3 miles, between a point north of Lina island and Slate Chuck creek. It extends inland, to the north, for about 2 miles; and since it is exposed on one small island, called Reef island, it extends to the south, below the water of Skidegate inlet, for about one mile. Its thickness is estimated as about 1,500 feet.

The member is composed largely of thin-bedded to shaly sandstone with more shaly interbeds. The rocks are not conspicuously carbonaceous, but are rather ferruginous and calcareous, and weather brown. Near the base and in the transition zone into the underlying Honna conglomerates, the shaly sandstones are partially to almost completely replaced along certain beds and fissures by calcite, and are cut by numerous calcite veinlets. These replacements are greyish white, although weathering black or reddish, and consist largely of a matrix of fine, opaque grains of calcite and chlorite in which are embedded angular quartz and slaty grains.

Structure of the Queen Charlotte Series.

The rocks of the Queen Charlotte series have a general synclinal or basin-like structure, with a long north-south axis and a comparatively short east-west axis, although near the southern end, at the Skidegate inlet, the area widens abruptly. Extending radially from the major basin, in the vicinity of Skidegate inlet, are four or five relatively narrow synclinal basins, which underlie fairly large valleys. As might be expected in the rather intense folding of a basin of irregular outline between ridges of metamorphic and crystalline rocks, the detailed structure is complex. Near Skidegate inlet the eastern limb of the basin is warped into rather open folds whose axes have a general north-south trend. The western limb, however, is involved in many folds and contortions. These become more nearly closed and the dip more nearly vertical, as the crystalline rock ridges, which here steeply surmount the denuded sedimentaries, are approached. For instance, in the 750-foot tunnel of the British Pacific Coal Company, north of the old Cowgitz mines, there are two folds, a syncline and corresponding anticline, while in the old Cowgitz mines the beds are 'either vertical or slightly overturned.'[1] In the interior of Graham island, the general structure of the basin is doubtless synclinal, although since the base of the series is apparently exposed on the three or four monadnocks of volcanic rocks, the general structure is not a simple syncline. There are also innumerable smaller folds, both open and closed, the closed folds usually occurring near the volcanic rocks.

The rocks of the series are broken also by numerous faults, including strike, dip, and oblique faults. Most of the faults noted were thrust or reversed faults, small and insignificant, and it is probable that they are not a very important factor in the general structure, although they will doubtless be troublesome if mining is carried on. The faults are most numerous near the borders of the basin where the rocks are most intensely folded, and near the dykes of porphyrite which cut the series. One fault, presumably an overthrust, bedding fault occurs at Image point, since there the fine conglomerates of the Haida member rest directly on the coarse basal conglomerates, there being no transition zone.

As noted, the Queen Charlotte series rests unconformably upon the older crystalline and metamorphic rocks of the Vancouver group and intrusive batholiths. The contact is usually marked by a basal conglomerate of variable character and thickness. The surface upon which the series was deposited was one of great relief, as is shown by the great variation in thickness of the Haida member, and it

[1] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., p. 73B.

seems as if three or four of the monadnocks which now surmount the sedimentary rock basin remained above the depositional level, at least throughout the period of deposition of the Haida member.

Intrusive into the Queen Charlotte series, largely restricted to the basal conglomerate and the Haida member, are numerous dykes and sills or laccoliths of dacite and andesite and basalt porphyrite. It is also possible that some of these igneous rocks are flows overlying the folded and eroded rocks of the Queen Charlotte series. These igneous rocks are largely of Tertiary age, and are described in more detail in a following section, under the heading of 'Tertiary volcanics and intrusives.'

Mode of Origin and Age and Correlation of the Queen Charlotte Series.

The Queen Charlotte series are apparently entirely of sedimentary origin, although it is possible that rocks of volcanic origin occur near the lower part of the series. The sedimentary rocks were deposited chiefly in a wide valley, now occupied by the Honna and Yakoun rivers, between highlands composed of pre-Cretaceous metamorphic and crystalline rocks. At the southern end the valley widened into a large basin, presumably draining eastward. It is also possible that this valley was open at the north end, and the extent of the Cretaceous sediments in this direction is unknown. In the valley itself were three or four large monadnocks, which remained above the depositional level during the formation of, at least, the lower member of the series.

The date of deposition of the series is generally considered to be Lower to Upper Cretaceous, so determined by Whiteaves[1] from the collections of Richardson, Dawson, Dr. Newcombe of Victoria, and Ells. Dawson[2] correlates the two upper members, the Skidegate (A) and the Honna (B) with the Upper Cretaceous, and considers them to be approximately equivalent to the Niobrara, Benton, and Dakota of the interior portions of North America, but just below the base of the Nanaimo series of Vancouver island, which is considered as the equivalent of the Pierre. Some question as to the age of the Haida member (C) has been raised, since some of its fossils are identical with middle Jurassic fossils of Alaska[3]. Consequently, Dowling[4] suggests that the fossils from the 'lower shales' (C) are from two formations. The writer has shown that at the base of the Haida member on Graham island is a basal conglomerate resting unconformably on Vancouver metavolcanics, and that it is probable that the two lower members of Dawson's Queen Charlotte formation are unconformably below the upper members. Also, the argillites of the southern part of Maude island unconformably underlying the Queen Charlotte series, are similar, lithologically, to the slaty and sandy shales of the Haida member, and contain a fossil which, as noted, is comparable with *Astarte carlottensis*, Whiteaves, supposed to come from the 'lower shales' (Haida member) of the Queen Charlotte series. Dowling's suggestion may, therefore, be correct and, if so, Dawson did not distinguish in every instance between the 'lower shales' (Haida member) and the argillites and sandstones of the Vancouver group, which unconformably underlie the Queen Charlotte series. This conclusion is further strengthened by the fossils which Dawson collected from the known Haida formation on Graham island, from the north shore of Bear Skin bay[5], which are all

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[1] Whiteaves, J. F., Mesozoic Fossils, Geol. Surv. of Can., vol. I, parts 1 (1876), 3 (1884), and 4 (1900).

[2] Dawson, G. M., Bull. Geol. Soc. Am., vol. XII, p. 75, 1901.

[3] Stanton, T. W., and Martin, G. C., Mesozoic Section on Cook inlet and Alaska peninsula: Bull. Geol. Soc. Am., vol. XVI, 1905, p. 402.

[4] Dowling, D. B., Bull. Geol. Soc. Am., vol. XVII, 1906, pp. 298–299.

[5] See list, Mesozoic Fossils, vol. I, part III, Geol. Surv. of Can., 1884, p. 255.

Cretaceous types, some of them distinctly Upper Cretaceous types; while those from other localities, not examined by the writer, are in some instances all Jurassic types, and presumably are from the argillites and sandstones of the Vancouver group.

Tertiary Volcanics and Intrusives.

Under the heading Tertiary volcanics and intrusives, are described a series of igneous rocks ranging from dacites to basalts, which are apparently all younger than the Queen Charlotte series, since they are intrusive into the Queen Charlotte series forming dykes, sills, and possibly laccoliths, and also flows which overlie not only the Queen Charlotte series but portions of the Tertiary sediments.

Distribution.—The Tertiary dykes and sills, chiefly dacite and andesite porphyrites, are found throughout the region underlain by the Haida sandstones and shales, and the dykes are even intrusive into the lower part of the Honna conglomerate. The dykes are, of course, more numerous in some places than in others, for example, north shore of the eastern part of Skidegate inlet, the west end of Skidegate inlet, Robertson camp and vicinity, east shore of Yakoun lake, Threemile creek, east of the large monadnock east of Wilson camp, and the middle part of Yakoun river, on section 24, township VIII, and section 30, township VII. The basalts occur chiefly as flows and surface formed fragmental rocks, and underlie the greater portion of the northern part of Graham island. They also occur capping the monadnocks, which surmount the basin underlain by the Queen Charlotte sediments, and apparently cap some of the mountains of the Queen Charlotte range to the east and to the west of the basin.

Lithological Characters.—As mentioned, the Tertiary volcanics and intrusives range from dacites to basalts, there being three or four more or less distinct types. The most 'acid' type is the dacite porphyrite. The most common variety of dacite porphyrite, which forms dykes, sills, and other comparatively small intrusive masses, is a light greenish grey, brownish-weathering, very fine grained to aphanitic or felsitic rock, in which are small but conspicuous laths of feldspar. The rock consists of andesine feldspar (ca. $Ab._{65}$ $An._{35}$), quartz, and originally hornblende with accessory magnetite. Almost invariably the alteration has been large, the secondary products being chiefly chlorite, sericite, and calcite. Calcite frequently replaces large volumes of the rock and occurs also as veinlets. Pyrite also occurs in disseminated grains and, weathering to limonite, stains the rock brown. Some varieties of the dacite porphyrite are conspicuously porphyritic. The phenocrysts are chiefly andesine feldspar (ca. $Ab._{60}$ $An._{40}$), although patches of dark minerals occur, probably secondary after hornblende phenocrysts. Quartz also forms small phenocrysts in some rocks. Otherwise the porphyritic varieties are similar to the non-porphyritic type, although the groundmass of the porphyritic varieties is the finer grained and in some rocks is spherulitic or glassy.

More rarely an andesite porphyrite forms dykes and sills. The andesite porphyrite resembles the porphyritic varieties of the dacite porphyrites, but contains no quartz and is even more conspicuously porphyritic, with numerous medium-sized, well-shaped phenocrysts of labradorite-andesine feldspar (ca. $Ab._{50}$ $An._{50}$), and smaller phenocrysts of hornblende and biotite.

The basalts of the northern part of Graham island, where they form flows, vary greatly in texture from glassy to porphyritic rocks, some being amygdaloidal, and from fine tuffs to rather coarse agglomerates. The most common type occurring in the vicinity of Masset Inlet expansion is a dark bluish grey, brown-weathering rock, with a few medium-sized phenocrysts of labradorite feldspar (ca. $Ab._{35}$

$An._{65}$), and numerous small phenocrysts of labradorite and augite in an aphanitic to glassy groundmass. The rocks are only slightly altered, epidote and chlorite being the chief alteration products.

In the central part of the island, capping the large monadnock east of Camp Wilson, is a basalt porphyrite similar in composition to the basalt described above but more coarsely crystalline, and with phenocrysts that greatly predominate over the groundmass, and also with small quartz phenocrysts. The rocks near the top of the monadnock are only slightly altered, while those exposed on the north side are much more altered than those on top, but seem to be of similar character and composition, although even more coarsely crystalline, with a much larger percentage of phenocrysts and of augite. These, in turn, overlie rocks which are of similar composition but which are even more altered and appear to be fragmental.

Structural Relations.—In most instances the structural relations of the Tertiary volcanics and intrusives are clear. Most of the dacite and andesite porphyrites occur as dykes and sills, up to 50 feet in width, which are intrusive into the Haida member of the Queen Charlotte series. In some places the sills follow the complex folding of the Haida member and have evidently been folded with it. In other places, the dykes and small irregular bodies cut sharply across the deformed rocks of the Haida member. The basalts of northern Graham island were evidently formed on the surface as flows and ash deposits, and have since been deformed, chiefly into rather broad open folds. These flows, in places, as noted by Ells[1] at Tow Hill, rest apparently upon a denuded surface of the Tertiary sediments, which are slightly metamorphosed at the contact.

The structural relations of the igneous rocks composing the large monadnocks in the central part of the island are, however, very obscure. The upper portion of these monadnocks in some instances, notably the largest one east of Camp Wilson, is composed of basalt porphyrite, which, as described, apparently grows coarser grained and more 'basic' downwards. This basalt porphyrite, as is shown in the No. 2 bore-hole of the Graham Island Coal and Timber Syndicate, situated near the southern line of section 4, township VII, and as is exposed in the creeks of the vicinity, apparently overlies greatly altered and in part fragmental basalts and andesites, that are similar to the meta-andesites and meta-basalts of the Vancouver group. In places, as along Threemile creek, on section 18, township VI, these altered rocks are overlain by conglomerates conformable with the Haida member and containing fragments identical with the underlying rocks. Similar pebbles are found in the conglomerates and pebbly sandstones associated with the coal seam at Camp Wilson; and on the southern slope of the large monadnock east of Camp Wilson are coarse arkose sandstones apparently resting unconformably upon the altered volcanics forming the base of the hill. On the northeastern slope of the monadnock, as is shown in the No. 1 bore-hole of the Graham Island Coal and Timber Syndicate, near the northeast corner of section 4, township VI, and as is exposed in the creeks of the vicinity, the metamorphic basalts and andesites are involved with dacite porphyrites, which cut the deformed rocks of the Haida member northeast of the volcanic rocks. Haida shales carrying fossils and overlying the altered volcanics are also reported on the north slope of the monadnock, in Canyon creek, but were not seen by the writer.

A conclusive interpretation of the facts stated above can not be given, but they strongly support the conclusion that the Haida sediments were deposited around old islands composed of the Vancouver meta-volcanics. Later the sediments were folded against these islands, and during and following the folding both

[1] Ells, R. W., Ann. Rept., vol. xvi, 1904, Geol. Surv. of Can., p. 24B, 1906.

the Vancouver meta-volcanics and the Haida sediments were intruded by dykes and sills of dacite and andesite porphyrite, the principal horizon of intrusion being the unconformity between the Haida sediments and the Vancouver meta-volcanics. All of the rocks were greatly denuded by erosion and were then intruded or possibly overflowed by the basalt porphyrites. However, since the basalt porphyrite bodies show no signs of bedding, and apparently have been subject to gravitative differentiation, it seems most probable that they are intrusive, either as thick sills or laccoliths.

Age.—The Tertiary volcanics and intrusives were probably erupted at various times through a long period. Part of the basalts of northern Graham island are younger or virtually contemporaneous with the Tertiary sediments, and hence are late Miocene or Pliocene, or younger. On the other hand, some of the dacite porphyrites were apparently intruded slightly before, during, or directly following the deformation of the Queen Charlotte series. Similar dacite porphyrites are found on Vancouver island[1] and in its vicinity. They are intrusive into the Upper Cretaceous sediments (Nanaimo series) and are considered to be of Eocene or post-Eocene age, the Nanaimo series having been deformed during a post-Eocene revolution. Hence it is probable that some of the dacite porphyrites of Graham island are at least as old as late Eocene. Farther north in the Ketchikan and Wrangell districts of Alaska are basaltic and rhyolitic volcanics of upper Eocene and of post-Glacial ages[2], so that it is possible that some of the basalts and andesites of Graham island may be of these ages. The volcanics and intrusives may range, therefore, from upper Eocene to post-Glacial, some of the basalts doubtless being of late Miocene or Pliocene age.

Tertiary Sediments.

Sediments of Tertiary age are exposed at widely separated localities in northern Graham island. The writer has seen them only at Skonun point on the north shore, but Dawson[3] and Ells[4] record outcrops at Yakan point and Tow Hill, to the east of Skonun point on the north shore, on Chinukundl brook on the east coast, and on Mamin river in the interior of the island, about 4 miles south of Masset inlet expansion. On the strength of these widely scattered outcrops, Ells maps the greater part of the northeastern lowland of Graham island to the east of Masset inlet as underlain by Tertiary sediments. However, since there are larger and more numerous outcrops of the Tertiary volcanics, and as there does not seem to be any geological break along Masset inlet, it seems best to consider the entire northeastern part of Graham island as underlain by Tertiary volcanics, although with a few, perhaps fairly large, areas of Tertiary sediments.

The sediments consist of partially consolidated to consolidated sandstones, clays, shales, and conglomerates, with beds of lignite, numerous, and fairly thick in places. The sandstones are cross bedded in places, and at Skonun point are fossiliferous. Dawson[5] states that on Mamin river the shales of Tertiary age, in which occur thin seams of lignite, appear to be, in part at least, of tufaceous character. The beds at Skonun point are moderately deformed. The structure is an anticline, with a general east-west strike, although the limbs of the anticline are deformed by transverse folds. The dips toward the shore vary from 25 to 60 degrees and those off shore vary from 15 to 25 degrees. The strata of the north

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[1] Clapp, C. H., Summary Report, 1911, Geol. Surv., Can., p. 106.
[2] Wright, F. E., and Wright, C. W., Bull. 347, U.S. Geol. Surv., pp. 72–73, 1908.
[3] Dawson, G. M., Rept. of Progress 1878–79, Geol. Surv. of Can., pp. 84B–89B.
[4] Ells, R. W., Ann. Rept., vol. xvi, 1904, Geol. Surv. of Can., pp. 23B–26B, 1906.
[5] Dawson, G. M., Rept of Progress, 1878–79, p. 89B.

and south limb of the anticline cannot be correlated with each other, so that the anticline appears to be broken along its crest by a fault. Near the supposed fault the beds of the southern limb bend sharply to the southwest. Ells states [1] that at Tow Hill the Tertiary shales are overlain by the Tertiary volcanics; and it appears from the nature of the contact as if the shales had been denuded before the volcanics overflowed them. At the contact they are slightly metamorphosed and 'interbedded with a thin sheet of black diabase'. The sediments of Chinukundl brook are, according to Dawson, only partially consolidated and appear, on the whole, to be nearly or quite horizontal. The Tertiary sediments, judging from their occurrence at Skonun point, appear to be off-shore marine deposits; and from the fanua collected by Dawson from the beds at Skonun point, the collection being examined by Whiteaves[2], their age appears to be Pliocene or late Miocene.

Superficial Deposits.

The northeastern lowland of Graham island is almost completely covered by superficial deposits, as is also much of the basin underlain by the Queen Charlotte series, and large areas in the lower, eastern portion of the Queen Charlotte range. The superficial deposits are of various kinds and origins. In the southern part of Graham island the superficial deposits, although extensive, are not very thick, since the underlying rocks are exposed in virtually every creek having a continuous flow. They are probably largely of glacial origin, chiefly boulder clay and till. Few good sections of the deposit are to be had, however, since they are either covered by heavy vegetation and humus, or by more recent alluvium, which underlies the extensive swamps or muskegs of this vicinity.

The deposits of the northeastern lowland have been rather fully described by Dawson[3]. They consist largely of a bottom layer, not always present, of boulder till, overlain by a stratified, plastic, blue, sandy clay and that in turn by stratified, frequently cross-bedded sands and gravels, that contain relatively thin interbeds and lentils of laminated, plastic clay. These deposits, which are at least 100 to 300 feet thick, are well exposed along the east and north shores of Graham island, along the shores of Masset inlet, and along the lower part of the Yakoun river. Some of the upper sands and gravels are locally consolidated by a ferruginous cement, making a fairly firm sandstone or conglomerate. Such locally cemented beds have been noted by Dawson along the east coast; and two outcrops, one at the mouth of the Nedo river, which empties into Masset inlet, and the other a mile to the south in the channel between Kumdis island and Graham island, at the east end of Masset Inlet expansion, were mistaken by Ells[4] for Cretaceous rocks. However, the locally hardened beds contain pebbles of the Cretaceous sandstones and Tertiary volcanic rocks, fragments of lignitized wood, and even Quaternary fossils. A bore-hole was put down in the southerly outcrop to a depth of over 100 feet. It passed through the locally cemented rock into the soft sands and clays below, and was abandoned. These stratified clays, sands, and gravels are fossiliferous and some of the upper clayey sands highly so. The fossils are chiefly marine pelecypods and gastropods, some of which still inhabit the island. These deposits are similar, as Dawson notes, to the superficial deposits of southeastern Vancouver island, which are of marine deposition and of interglacial age and are overlain by a younger glacial drift[5]. No younger glacial drift was noted on Graham island,

[1] Ells, R. W., Ann. Rept., vol. xvi, 1904, p. 24B, 1906.
[2] See Rept. of Progress, Geol. Surv. of Can., 1878–79, p. 87B.
[3] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., pp. 89B–94B.
[4] Ells, R. W., Ann. Rept., vol. xvi, 1904, p. 26B, 1906.
[5] Clapp, C. H., Geology of the Victoria and Saanich Map-areas: Memoir No. 36, Geol. Surv., Can., 1913.

and the deposits may be of interglacial or post-Glacial age. They are, however, unquestionably of marine origin, although their material is composed largely of glacial detritus.

Besides the stratified clays and sands and gravels, there are on the northeast lowland, fairly thick deposits of recent alluvium. At the mouths of some of the larger streams, such as the Yakoun river, river gravels and delta silt are abundant. Many of the post-Glacial swamps and lakes have been filled with silt and, along the north coast, barrier beaches and bay bars have been formed in the lea of which are salt marshes. These recent deposits have apparently been uplifted at least 15 feet since the country became inhabited[1], although there has been a still-stand of the land for a long time. Along the north shore, the uplifted sands and gravel deposits have been beached, and sand dunes have been formed, which have migrated inland for a short distance.

Economic Geology.

The writer's reconnaissance on Graham island was devoted chiefly to the coal deposits of the island, and little time was given to the other mineral resources. Doubtless, in the mountain region of the island, there are contact-metamorphic and other mineral deposits similar to those of Moresby island[2], possibly valuable for iron, copper, and gold. There are also deposits of limestone and, along the east coast of the island, some gold has been found in the beach sands. The mineral resources of the region examined by the writer are, however, virtually confined to coal, possibly oil, and clay. Some prospecting has been done in the mineralized sheared zones in both the Vancouver and the Tertiary volcanics, but barren pyrite is the only abundant metallic mineral. Lenses of clay iron-stone occurring in the carbonaceous slaty shales of the Haida formation have been mentioned as sources of iron ore[3], but since the lenses are small and of limited distribution, it is very improbable that they will ever furnish any ore.

COAL.

Coal is found in the Queen Charlotte series, presumably of Cretaceous age, and in the Tertiary sediments. The coals from the Queen Charlotte series, or, as they will be called, the Cretaceous coals, range from a semi-anthracite or high carbon bituminous to a low carbon bituminous. The Tertiary coals are lignites, most of them brown, with a woody or fibrous structure, although some are black, with an irregularly coaly structure and conchoidal fracture.

Cretaceous Coals.

The Cretaceous coals occur in the Haida member of the Queen Charlotte series; and, as far as one can tell, all of the seams occur at about the same horizon, 200 to 500 feet below the top of the Haida member (or the base of the Honna conglomerate) and from less than 100 feet to 4,000 or 5,000 feet above the base of the series. The variation in the character of the coal is apparently due to the relative amount of local deformation and igneous intrusion. Coal has been found at several places. The better known of these places are: near the west end of Skidegate inlet at Cowgitz and vicinity, in the south central part of the basin of the Queen Charlotte series (see sketch map) at Camps Robertson and Anthracite, and in the north central part of the basin at Camp Wilson. The coal occurrences at these places will be first described and then the possible extension of the known coal seams will be considered.

[1] Dawson, G. M., Rept. of Progress, 1878–79, Geol. Surv. of Can., p. 95B.
[2] McConnell, R. G., Summary Report for 1909, Geol. Surv., Can., pp. 72–83.
[3] Marshall, T. R., Rept. Min. Mines, B.C., 1902, p. H55.

Cowgitz and Vicinity.—Coal was apparently first discovered on Graham island at Cowgitz near the head-waters of Hooper creek and its tributary Robertson creek. Previous to 1872, a rather extensive attempt at mining was made, but the operations proved unsuccessful. A fairly detailed description of the coal deposits and of the prospecting is given by Richardson[1] and Dawson[2]. Two seams, or the same seam repeated by folding, were discovered, one 6 feet thick and the other 2 feet 5 inches thick. The seams were vertical, the measures being greatly disturbed, and the 6-foot seam apparently rested against the trap rocks of the underlying Vancouver volcanics. There is, however, some doubt about this, since the measures are cut by dykes and sills of dacite and andesite porphyrite which were not clearly distinguished by the earlier writers from 'trap' and 'feldspathic sandstone'. The coal seams and the associated carbonaceous slaty shales were badly crushed, and the coal seams could be followed only with great difficulty. In addition, the coal was dirty, and frequently pulverulent and mixed with debris from the slaty shales. In 1872, the project was abandoned. A later attempt at mining was made about 1890.

During 1912, another attempt was begun by the British Pacific Coal Company, to the north of the old workings, between them and Slate Chuck creek, in the northeast portion of section 14, township II. Here, the measures, although considerably deformed, are not greatly crushed. An adit or 'tunnel' bearing S. 35° W., has been driven across the strike of the measures for 757 feet, and three seams of over a foot in thickness have been encountered. These are called the 'A,' 'B,' and 'C' seams, the 'A' seam being the lowest and the nearest to the entrance. The seams

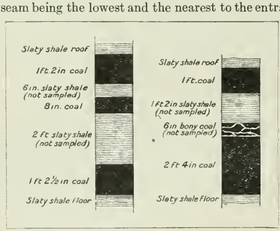

Fig. 2.—Sections of 'B' and 'C' seams exposed in tunnel of British Pacific Coal Co., section 4, Tp. II, Graham Island, B.C.

are associated with slaty shales, usually carbonaceous, intrusive into which are at least two sills of altered dacite porphyrite. The dacite porphyrite sills do not appear to have broken across the bedding, and may have been folded with the shales. In the length of the 'tunnel,' which ascends in the formation, the measures are involved in a fairly sharp syncline, with a corresponding broader anticline. The rocks and seams are also broken by one or two small transverse faults.

The 'A' seam is 6 feet thick and consists of a somewhat crushed coal, which has the appearance of being graphitic. The 'B' seam is 5 feet 6½ inches thick, and the 'C' seam is 5 feet thick. The coal from these two seams is not greatly crushed. Detailed sections of these seams are given above (Figure 2).

[1] Richardson, James, Rept. of Progress, 1872–73, Geol. Surv. of Can., 1873, pp. 57–60.
[2] Dawson, G. M., Rept. of Progress 1878–79, Geol. Surv. of Can., 1880, pp. 71B–77B.

Analyses of Coals from Tunnel of British Pacific Coal Co., Graham Island, B.C.

	1	2	3
Proximate analyses:—			
Water	6·68	6·85	6·69
Vol. combustible	6·28	5·43	6·59
Fixed carbon	68·49	66.32	57·23
Ash	18·55	21·40	29·49
	100·00	100·00	100·00
Coke	87·04	87·72	86·72
Its character	(non-coherent).		
Fuel ratio	10·91	12·21	8·69
Split volatile ratio	7·29	7·21	6·05
Ultimate analyses:—			
Carbon		65·0	63·5
Hydrogen		2·05	2·05
Nitrogen } Oxygen }		8·5	8·1
Sulphur		0·2	0·3
Moisture		5·3	5·3
Ash		24·2	26·0
Carbon-hydrogen ratio		31·7	31·0

1. Coal from 'A' seam. 2. Coal from 'B' seam. 3. Coal from 'C' seam.

The following analyses are the others, which are available, of the coals of the Cowgitz district:—

	1	2	3	4	5	6
Water	1·60	1·89	6·60	6·45	6·75	6·77
Vol. matter	5·02	4·77	3·95	4·15	4·25	4·23
Fixed carbon	83·09	85·76	68·17	63·60	65·50	85·48
Ash	8·76	6·69	21·28	25·80	23·50	3·52
Sulphur	1·53	0·89	0·43	0·45	0·34	0·42
	100·00	100·00	100·43	100·25	100·34	100·42
Coke	(non-coherent).					
Fuel ratio	16·5	17·9	17·3	15·3	15·4	20·2

1.—6-foot seam at Cowgitz.
2.—2-foot 5-inches seam at Cowgitz. J. Richardson, collector; B. J. Harrington, analyst. Geol. Surv. of Canada, Rept. of Progress, 1872–73, p. 81.
3, 4, 5, and 6.—Different benches from the 'B' seam, tunnel of British Pacific Coal Co. Alexander Faulds, collector; Noble W. Perrie, analyst. Furnished by British Pacific Coal Company.

The coal from these seams, as may be seen from the analyses given above, is a high ash semi-anthracite. It is, however, rather strangely high in water, in this respect being similar to the anthracite coals of the Groundhog basin in the northern interior portion of British Columbia[1]. The following analyses are from samples collected by the writer; the sample from the 'A' seam is a grab sample, while those from the 'B' and 'C' seams were made by cutting across the seam, eliminating the

[1] See List of Analyses. G. S. Malloch, Summary Report, Geol. Surv., Can., 1911, pp. 88–90.

partings, as shown in the detailed sections given in Figure 2. The proximate analyses were made by F. G. Wait in the laboratory of the Mines Branch, Department of Mines, Ottawa, and the ultimate analyses were made by E. Stansfield in the Fuel Testing laboratory of the Department of Mines.

Camps Robertson and Anthracite.—The writer spent only a few hours at Camp Robertson, and at present there is little to be learned there, so that the following description is condensed, chiefly from the description given by Ells[1]. At Camp Robertson, near the western boundary of section 20, township V, there appear to be two coal seams, totalling 20 to 25 feet in thickness, with perhaps 15 feet of fairly clean, but high ash, bituminous coal. The seams have been opened along the outcrop for a distance of 295 feet. They have a strike of near N. 40° W., with dips to the northeast, varying from 75 to 16 degrees, the flatter dips occurring farther to the northeast. In the opening at the southeast end of the outcrops the two seams are separated by 8 feet of shale, which thins out to the northwest to a thin parting.

The measures in the vicinity of Camp Robertson consist chiefly of green, very fine, in places argillaceous, to coarse grained sandstones, composed of the mechanically disintegrated detritus from the Vancouver volcanics, and sandy conglomerates. Some of the beds are carbonaceous, and coaly lenses and tree trunk impressions are common. The rocks are greatly deformed and cut by numerous dykes of dacite and andesite porphyrite. The detailed structure could be worked out only by a prolonged and detailed examination and development. It appears, however, that the general structure in the immediate vicinity is a narrow syncline, striking about N. 40° W. and pitching and perhaps widening to the southeast. In the vicinity of Camp Robertson the width of the syncline underlain by the horizon of the coal seams is probably less than 1,000 feet. There is, however, farther to the northeast, a broader syncline, separated from the first by a narrow anticline. It is probable that the anticline ends to the southeast, the two synclines becoming one and forming the northern portion of the major syncline of the Queen Charlotte series extending to Skidegate inlet.

	1	2	3	4	5
Water	0·80	1·33	1·20	1·52	2·85
Vol. matter	23·27	35·25	29·13	8·69	7·59
Fixed carbon	51·39	42·57	47·52	80·07	68·25
Ash	24·54	20·85	22·15	9·72	21·31
	100·00	100·00	100·00	100·00	100·00
	(firm,	coherent	coke)	(non-coherent	coke)
Fuel ratio	2·21	1·39	1·63	9·21	8·99

1.—Camp Robertson, W. A. Robertson, collector; G. C. Hoffmann, analyst; vol. VI, 1892–93, Geol. Surv. of Can., 1895, p. 12R.
2.—Camp Robertson, lower seam, R. W. Ells, collector; J. T. Donald, analyst; vol. XVI, 1904, Geol. Surv. of Can., 1906, p. 43B.
3.—Camp Robertson, R. W. Ells, collector; M. F. Connor, analyst; vol. XVI, 1904, Geol. Surv. of Can., 1906, p. 44B.
4 and 5.—Camp Anthracite, W. A. Robertson, collector; G. C. Hoffmann, analyst; vol. VI, 1892–93, Geol. Surv. of Can., 1895, p. 13R.

It is possible that the Robertson coal seams, which are exposed in the southwestern limb of the syncline, extend about a mile to the southeast, since coal seams also occur at about the same horizon at what is known as Camp Anthracite in the

[1] Ells, R. W., Ann. Rept., vol. XVI, Geol. Surv. of Can., 1906, pp. 40B–44B and p. 35 B.

northern part of section 17, township V. Here, the measures strike about N. 50° W., and the dip is steep to the northeast. The rocks are, however, greatly deformed and broken, and the coal, which is anthracitic in character, is impure.

As stated, the coal from Camp Robertson is of a bituminous character. Apparently the change to the anthracitic coal, really semi-anthracitic, of Camp Anthracite, is due to the local deformation and intrusion of igneous rocks. The available analyses of the coals from Camps Robertson and Anthracite are given on page 32.

Camp Wilson.—Camp Wilson is situated on Wilson creek, about a mile southeast from the junction with the Yakoun river, probably in the northern part of section 25, township IX, although according to the old surveys it was located on section 36, township IX. At Camp Wilson the most promising of the coal seams of Graham island has been opened up by a small amount of development work. The measures associated with the coal seam, which has a maximum thickness of nearly 17 feet, are a roof of greenish grey pebbly sandstone and conglomerate, and a floor of coarse bluish green sandstone, 30 feet thick, overlying carbonaceous sandy shale. The measures in the immediate vicinity are fairly uniform, and are not greatly broken, although they are considerably deformed. The general strike is N. 10°–20° W., with a steep dip 60°–80° to the northeast. Up Wilson creek, to the southeast, the measures are involved in many small, rather open folds. To the northwest, the exposures are few, but the folds seem to be rather open; to the east, however, is the largest of the monadnocks that surmount the basin underlain by the Queen Charlotte series. It is composed of the Vancouver meta-volcanics capped by the Tertiary volcanics and intrusives, and it apparently remained above the depositional level during the formation of the Wilson seam. On the southwest slope of the monadnock, coarse basal sandstones apparently lie on the Vancouver volcanics. There the general structure appears to be a fairly open but narrow syncline, fringing the monadnock.

The development work at Camp Wilson consists of a small adit, near the entrance of which is a shaft 14 feet deep, which affords access to a lower level in which the seam is best exposed. A plan of the development work is given in Figure 3.

The seam, which strikes N. 10° W., and dips 80° to the northeast, varies from 5 feet to nearly 17 feet in thickness. It apparently pinches to less than 3 feet at the face of the upper level, but this is probably due to the erosion and slumping of the seam, which at that point is directly overlain by surface drift. As shown in the lower level, the seam is broken by a small obliquely transverse fault, and the bedding planes of the coal seam are slickensided, but there do not appear to be any conspicuous faults. The seam may be traced southeast for about 400 feet to a small shaft. It appears, therefore, that the seam is fairly continuous, and that it is not a lens of coal, such as are common in the measures overlying the workable seams of the Nanaimo district of Vancouver island. The local thickening of the seam is not unusual, and is a characteristic feature of the seams of the Nanaimo and Comox districts[1].

The coal is a low carbon bituminous. The clean coal is bright, not greatly fractured, and hard and splintery, while the dirty coal, as at Nanaimo, is dull, greatly broken, and slickensided. A detailed section of the seam across its thickest portion is shown in Figure 4, and an analysis of a sample taken from the same section, with the parting eliminated, is given below. The sample was collected by the writer, the proximate analysis was made by F. G. Wait in the laboratory of the Mines Branch of the Department of Mines, and the ultimate analysis was made by E. Stansfield in the Fuel Testing laboratory of the Department of Mines.

[1] Clapp, C. H., Summary Report, Geol. Surv., Can., 1911, pp. 91–107. Also—Trans. Can. Min. Inst., vol. xv, 1912, pp. 334–353.

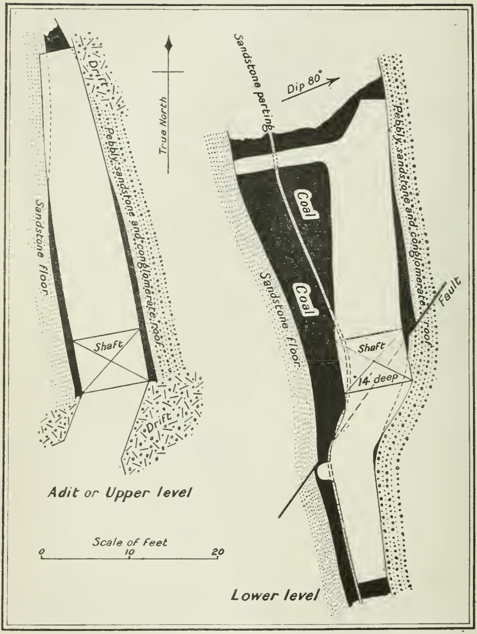

Fig. 3. Plan of development on coal seam at Camp Wilson, Graham island, B.C.

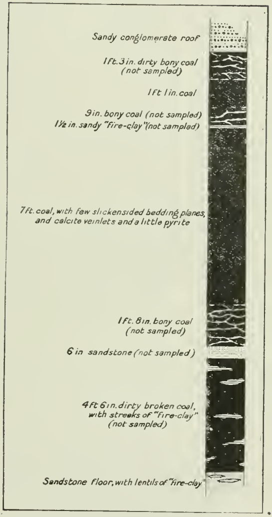

Fig. 4.—Section of coal seam at Camp Wilson, Graham island, B.C.

Proximate analysis:—

Water	2·44
Vol. combustible	35·96
Fixed carbon	48·64
Ash	12·96
	100·00
Coke	61·60
Its character	firm, coherent
Fuel ratio	1·35
Split volatile ratio	3·26

Ultimate analysis:—

Carbon	70·6
Hydrogen	4·8
Nitrogen, Oxygen	9·5
Sulphur	0·8
Moisture	2·0
Ash	14·3
Carbon-hydrogen ratio	14·0

The other available analyses of the Camp Wilson coal are given below:—

	1	2	3	4
Water	2·65	1·06	2·47	1·91
Vol. matter	38·19	43·48	35·25	35·24
Fixed carbon	53·73	46·01	59·36	59·39
Ash	5·43	9·45	2·92	3·46
	100·00	100·00	100·00	100·00
		(firm coherent coke)		(non friable coke)
Fuel ratio	1·41	1·06	1·68	1·68

1.—G. C. Hoffmann, analyst, Ann. Rept. vol. III, 1887–88, Geol. Surv. of Can., 1889, p. 17T.
2.—W. A. Robertson, collector; G. C. Hoffmann, analyst; Ann. Rept., vol. VI, 1892–93, Geol. Surv. of Can., 1895, p. 12R.
3.—R. W. Ells, collector; J. T. Donald, analyst; Ann. Rept., vol. XVI, 1904, Geol. Surv. of Can., 1906, p. 40B.
4.—R. W. Ells, collector; M. F. Connor, analyst; Ann. Rept., vol. XVI, 1904, Geol. Surv. of Can., 1906, p. 44B.

Minor Occurrences.—Three other occurrences of coal have been noted on Graham island, but none of them are of any commercial importance. One, the so-called 'Number Two Mine' of the old Cowgitz company, is situated on the south side of Long arm, near Saltspring bay, southeast of Steep point. According to Richardson[1] there is there a 2- to 3-foot seam of 'culm' (thin-bedded carbonaceous sandy shale) with small lenses of coal. Another is found on the south side of Skidegate channel, between Skidegate inlet and the Pacific ocean, almost 4 miles west of Skidegate inlet. Dawson[2] describes the occurrence as a small broken syncline, with an east-west axis parallel to Skidegate channel, of grey feldspathic sandstones (dacite porphyrite sills?) interbedded with dark argillites (carbonaceous sandy and slaty shales). On the north limb of the syncline the so-called sandstones hold small fragments of anthracite. The third occurrence is near the southeast angle

[1] Rept. of Progress, 1872–73, Geol. Surv. of Can., p. 60.
[2] Rept. of Progress, 1878–79, Geol. Surv. of Can., p. 68B, 1880.

of Yakoun lake, and is described by Ells[1]. There, there is a small basin of crushed, black coaly shale in which occur irregular stringers of impure anthracite.

Extension of Coal Fields and Coal Reserves.—Those areas, which, so far as our knowledge goes, are, with a high degree of probability, underlain by coal seams, are small. They consist merely of 1·1 square miles in the vicinity of Cowgitz, 0·8 square miles in the vicinity of Camp Robertson, and 0·3 square miles at Camp Wilson. The first consists of two connected basins occupying Slate Chuck Creek valley and the valley to the south. The measures are greatly deformed, and there are doubtless several complete folds. The measures are also cut by dacite and andesite porphyrite dykes. There are, in places, at least three seams of coal which is semi-anthracite in character. If the total workable thickness of these seams is taken as 6 feet over the area, the reserve, allowing 1,000,000 tons per square mile-foot, is about 3,300,000 long tons. The second area, at Camp Robertson, consists, as already described, of a closely-folded synclinal basin, cut by dacite and andesite porphyrite, 600 to 2,000 feet wide and almost 2 miles long. There appears to be virtually only one seam of a high ash, bituminous to anthracitic coal, and if its average thickness is taken as 3 feet, the coal reserve would be 2,400,000 long tons. The third area, at Camp Wilson, consists of a long, folded synclinal basin hardly more than half a mile long and 600 to 700 feet wide. There is at least one seam of a good quality bituminous coal, and if its average thickness is taken as 4 feet, the coal reserve would be 1,200,000 long tons.

It is perhaps probable, or possible, that the coal seams exposed on the west limb of the Skidegate Inlet-Honna River basin, exposed near Cowgitz and at Camps Robertson and Anthracite, extend beneath the basin and underlie the greater part of the area underlain by the upper part of the Haida member and the Honna and Skidegate members of the Queen Charlotte series. This possibility has never been proved or disproved, as no systematic prospecting has ever been carried on in the east limb of the syncline except below the coal horizon. The prospecting of this limb by bore-holes located just below the base of the Honna conglomerate is very strongly recommended. If coal were found here it would indicate strongly that coal would be found beneath the entire syncline. At no place in the syncline is the coal horizon more than 4,000 feet deep and over much the larger part of the syncline it is less than 2,500 feet. Another feature strongly in favour of the prospecting of the east limb is the fact that the measures of the east limb are much less deformed than those of the west limb, and are cut by fewer dykes of dacite and andesite porphyrite. The area underlain by the syncline under which there is a fair possibility of finding coal, is about 57 square miles. If the average thickness of the coal, which would be largely of a bituminous character, be taken as 5 feet, the possible reserve, or reserve of a low degree of probability, would be 285,000,000 long tons.

It is also probable that the Camp Wilson syncline extends to the northwest, thence turning to the northeast, fringing or collaring the west flank of the monadnock east of Camp Wilson. It may also, although with a less degree of probability, extend farther to the southeast. The total area of the syncline that may be considered as probably underlain by coal is, however, only 0·8 square miles. With the average thickness of the seam taken as 4 feet, this would give a probable reserve of 3,000,000 tons. On account of the high-grade character of the known coal, the prospecting of the northwest extension of the Camp Wilson syncline is strongly recommended.

It does not seem probable that the minor occurrences of coal described above indicate basins of coal of any great commercial value. Neither does there seem to be much possibility of finding commercial coal in the other parts of the basin

[1] Ann. Rept., vol. XVI, 1904, Geol. Surv. of Can., p. 32B, 1906.

underlain by the Queen Charlotte series, with the exception of a small syncline area, somewhat over one square mile, in the central part of township VI, in the valley of Threemile creek.

It has been seen that while the 'actual reserve' of Cretaceous coals, that is the reserve of a high degree of probability, is small, only about 6,900,000 tons, the reserve of a fair degree of probability is rather large, about 293,000,000 tons.

Tertiary Coals.

The Tertiary coals, which, as stated, are all lignites, occur in the Tertiary sediments, which are confined to the northeastern part of Graham island. Lignite is known to occur at several localities, the best known of which is Skonun point on the north shore. This was the only locality visited by the writer, and will be described in more detail. Dawson[1] describes briefly the occurrence of lignite at a few other localities. In Chinukundl brook, which empties into Hecate strait 8 miles north of Image point, are a few thin, impure seams. North of Chinukundl brook, between Lawn hill and Cape Fife, numerous fragments of lignite are found on the beach, suggesting that lignite may outcrop in the vicinity possibly below low-water mark. At Yakan point on the north shore, about 10 miles east of Skonun point, irregular masses of lignite are found in sandstones and shales. Six miles up the Mamin river, which empties into Tsuskatli arm of Masset Inlet expansion, lignite occurs in thin seams. In the bed of a stream emptying into the east side of Naden harbour, pieces of lignite abound, and they have probably come from some outcrop not far up the stream. Also, the writer has seen samples of a good grade of black lignite with an irregular coaly structure and conchoidal fracture, that probably came from the northeast part of the basin underlain by the Queen Charlotte series near the head-waters of Tlell river.

At Skonun point at low tide there are exposed more than ten seams of varying persistency, of a tough woody lignite, which is curiously more resistant to wave erosion than the sandy shales with which it occurs. The seams range from 1 to 15 feet in thickness. As described under Tertiary sediments, the lignite bearing measures have been considerably deformed, the structure apparently being a small anticline with a general east-west strike, broken along the crest by a nearly due strike fault. The southern limb of the anticline contains the lignite seams, which dip inland at angles varying from 25 to 60 degrees. An inclined bore-hole has been put down to a depth of 1,000 feet in the property, which is controlled by the American-Canadian Coal Company. It is reported that thirteen seams of lignite of more than a foot in thickness were struck in this distance. Near the surface, the lignite is of the same woody nature as that exposed in the beach, but it is said that the lignite found in depth is of a more coaly nature.

The character of the lignite exposed at the surface is shown by the following proximate and ultimate analysis of a thoroughly air-dried sample collected by the writer from the thickest seam. The proximate analysis was made by F. G. Wait in the laboratory of the Mines Branch, Department of Mines, and the ultimate analysis was made by E. Stansfield in the Fuel Testing laboratory of the Department of Mines.

Proximate analysis:—

Water	11·03
Vol. combustible	49·75
Fixed carbon	35·94
Ash	3·28

[1] Rept. of Progress 1878–79, Geol. Surv. of Can., pp. 85B–89B, 1880.

Coke	39·22
Its character	coherent, but tender.
Fuel ratio	0·72
Split volatile ratio	2·33

Ultimate analysis:—

Carbon	56·3
Hydrogen	5·9
Nitrogen	0·3
Oxygen	33·1
Sulphur	0·3
Moisture	10·0
Ash	4·1
Carbon hydrogen ratio	9·5

Two other analyses of the Skonun Point lignite are published in the prospectus of the American Coal Company, September, 1911, the analyses being made by J. O'Sullivan, of Vancouver.

Water	22·0	22·5
Vol. combustible	45·5	37·5
Fixed carbon	31.5	36·5
Ash	1·0	3·5
	100·0	100·0

The actual coal reserve at Skonun point is large. The seams are exposed for a distance of half a mile along the beach, as far as any outcrops are observed, and they undoubtedly extend much farther. If the area underlain by the lignite is estimated, very conservatively, as being 2 square miles, the reserve, taking 30 feet as the average thickness of workable seams of lignite, is 60,000,000 long tons. The lignite reserve of a fair degree of probability, on Graham island, is much greater. The areas underlain by Tertiary sediments, which almost assuredly contain more or less lignite, throughout the northeastern part of the island, may be conservatively estimated as totalling 136 square miles, and the probable lignite reserve is at least 1,000,000,000 long tons. It is, therefore, not a question of the quantity of the lignite, but of its quality and commercial possibilities.

Although some of the lignite is of a high grade, coaly character like the lignite described as probably coming from near the head-waters of Tlell river, most of it will doubtless be a lower grade character, like that exposed at Skonun point. However, the lignite that has been seen by the writer is strong and does not slack on exposure to the air like the lignites of the prairie regions. It is, therefore, capable of being transported and of being used directly as a fuel. Also many of the lignites, certainly those of Skonun point, are low in ash. The high water or oxygen content is, of course, a great drawback, since these substances greatly reduce the calorific (heat) value of the lignite. Nevertheless, of late years a great deal of attention has been given to the lignites of North America, and economical processes for their use have been developed. Hence, the lignites of Graham island are of great future value.

OIL.

Prospecting and boring for oil has been in progress for some years along the west coast of Graham island, between Tian point and Frederick island. There are here considerable thicknesses, although probably occurring in small areas, of dense bituminous shales, of Upper or Lower Cretaceous age, overlain by Tertiary basaltic lavas. Similar shales occur also to the west of the main basin of Cretaceous sediments (the Queen Charlotte series) between the Yakoun river and the west coast. The shales have a strong odour of petroleum and small seepages of petroleum and tarry matter are common along the west coast, the tar in places

filling crevices in the overlying basalts. Also, a large mass of very pure ozocerite, or natural paraffine, has been found in the vicinity. As yet, the prospecting and boring has been carried on without success.

CLAYS.

Graham island abounds in clays and shale-clays suitable for common brick and other products made from low grade clays, and it is possible that some of the shale-clays are of fairly high grade. Shale-clays are found in the Haida member of the Queen Charlotte series and in the Tertiary sediments, although those found in the Tertiary sediments are but slightly indurated. Thick and very extensive beds of clay also occur in the superficial deposits.

Most of the finer grained argillaceous rocks of the Queen Charlotte series are sandy and somewhat metamorphosed, and resemble slates more than shales. They are consequently of poor plasticity, and unsuitable for use as clays. In a few places, however, the shales are softer and of fair plasticity, and doubtless could be worked in a stiff mud process. They are also of fairly high fusibility and of low air and fire shrinkage. Two of the shales from the Haida member, exposed on the property of the British Pacific Coal Company, Section 14, township II, below the 'A' coal seam, were tested by Prof. H. Ries. The upper shale, 15 feet in thickness, is a dark carbonaceous, dense slaty shale, similar to that quarried by the Indians on Slate Chuck creek for carving into various objects. The lower shale, 30 feet in thickness, is a lighter coloured and much softer rock, containing a larger percentage of kaolin, and is locally called 'fireclay.' Professor Ries reports on these clays as follows:—

> 'The plasticity of the lower shale is fair, that of the upper shale very poor. A mixture of the two shales in equal proportions is fairly plastic. The air shrinkage of the mixture averages 4·5 per cent, and the tensile strength averages 50 pounds. At cone 010 (1742° F. or 950° C.) the burnt mixture has a little ring, poor colour, an absorption of 14 per cent, and a fire shrinkage of minus 1 per cent. At cone 05 (1922° F. or 1050° C.) the mixture has a light grey buff colour and an absorption of 13 per cent. At cone 1 (2102° F. or 1150° C.) the colour is still the same and the fire shrinkage 1·6 per cent. At cone 7 (2318° F. or 1270° C.) the mixture shows no sign of failing by fusion. These tests show that the mixture could be used for common and face brick, although there was not sufficient material supplied to test it in a stiff mud die. The lower shale clay alone behaves similarly, but is more plastic and burns a little denser.'

The shale-clays of the Tertiary sediments were seen by the writer only at Skonun point on the north shore. Those exposed in the beach are sandy, but it is probable that the softer, more plastic clays are unexposed. Such clays were, however, found in abundance in the bore-hole put down at Skonun point. They are light grey clays of good plasticity. Their air shrinkage does not seem to be very high. It is not probable that their fire-resisting qualities are high, but they could doubtless be used for common brick, drain tile, and similar wares.

The clays of the superficial deposits are virtually confined to the stratified deposits of the northeastern lowland, but these are in great abundance, and presumably extend over the entire lowland. They are bluish grey, sandy clay of good plasticity. They are similar in quality to the surface clay used extensively near Victoria for common brick and drain tile.

GEOLOGY OF PORTIONS OF THE SOOKE AND DUNCAN MAP-AREAS, VANCOUVER ISLAND, BRITISH COLUMBIA.

(Charles H. Clapp).

Introduction.

The greater part of the field season of 1912 was spent by the writer and his assistants in a geological examination of a portion of southern Vancouver island. The Sooke and Duncan topographic maps, prepared in 1910 under the direction of R. H. Chapman, were used as field maps. These maps consist of two thirty-minute sheets, mapped on a scale of 1:96,000 (1 inch=8,000 feet), for publication at about 2 miles to 1 inch, with topography shown by contours at an interval of 100 feet. The total land area on Vancouver island and adjacent islands (the southern sheet, the Sooke, includes a part of the state of Washington, which will only be shown in outline) represented by the maps, is about 825 square miles. This includes that portion of Vancouver island south of the 49th parallel, which passes through the northern part of the town of Ladysmith, between longitudes 123° 30′ and 124°, also several small islands off the east coast of Vancouver island, and portions of Saltspring and Galiano islands. The geological mapping of only a portion of the total area covered by the topographic maps was completed during the season. This portion, about 370 square miles in area, and all on Vancouver island, includes the entire Sooke map-area, except the East Sooke peninsula and the southern portion of the Rocky Point peninsula, and includes also the greater part of a strip, 5 to 10 miles wide, extending across the southern part of the Duncan map-area.

During the mapping the writer was very ably assisted, until the latter part of August, by Mr. W. L. Uglow, who was in charge of the party during the writer's absence, necessitated by a month's trip to Graham island. The other assistants were Mr. Victor Dolmage and Mr. Angus McLeod. During part of the season, considerable geological aid was also given by Mr. Roy H. Allen and Mr. James Caffery. Information was supplied by the Western Canadian Oil Prospecting Company, who have been prospecting for oil near the mouth of Muir creek; and acknowledgment is due the Jordan River Power and Development Company, who gave the field party much assistance in transportation in the vicinity of Jordan river.

Previous Work.

No detailed geological work had been done previously on the Sooke map-area or on the southern part of the Duncan map-area. In 1876, Dawson made a reconnaissance of Leech river and vicinity, paying especial attention to the origin and extent of the placer deposits. The result of his work is given in the Report of Progress of the Geological Survey of Canada for 1876–77, pages 95–102. In 1902, Webster and Haycock examined a portion of the coast of the Sooke map-area. Their report is published in the Summary Report of the Geological Survey for 1902, pages 54–59. In 1908, 1909, and 1910, the writer made reconnaissances over the southern part of Vancouver island, including the entire area mapped during the present field season. The results of his reconnaissances are presented with considerable detail in Memoir No. 13, Geological Survey of Canada, 1912,

with a reconnaissance geological map of southern Vancouver island. Since the area is treated rather fully in that memoir, as well as in the writer's summary reports, many of the subjects will be treated only briefly in this report, especial emphasis, however, being laid on those results obtained during 1912, which confute or support the writer's previous conclusions.

Summary and Conclusions.

GENERAL GEOLOGY.

The oldest rocks of the Sooke map-area and of the southern part of the Duncan map-area, are a series of greatly deformed and partly schistose sedimentary and volcanic rocks, the Leech River formation and the Malahat volcanics. They are more metamorphosed and apparently older than the Vancouver volcanics and are assigned provisionally to the Carboniferous.

The lower Mesozoic rocks, constituting the Vancouver group, consist of the Vancouver volcanics and the Sutton formation. The Vancouver volcanics are chiefly meta-andesites. Intercalated in the Vancouver meta-volcanics but also occurring as isolated lentils in the intrusive granitic rocks, are the crystalline limestones of the Sutton formation.

Intrusive into the metamorphic Palæozoic and lower Mesozoic rocks are batholiths and stocks of granitic rocks, which were irrupted during one general period, probably in upper Jurassic time, and which are correlated with the Coast Range batholith. Considered in detail, the granitic rocks are subdivided into three types, which were irrupted in a definite sequence, as follows: Wark gabbro-diorite gneiss, Colquitz quartz-diorite gneiss, and Saanich granodiorite. The first two types, which form virtually a single batholith, have been dynamo-metamorphosed, but their gneissic structure is considered to be a primary feature.

In the southern part of the area is a thick series of basaltic rocks of upper Eocene age, that are called the Metchosin volcanics. These have been deformed in post-Eocene time and intruded by stocks, the Sooke intrusives, composed chiefly of gabbro, but with differentiates of feldspathic gabbro and quartz diorite. These rocks are separated from the Palæozoic and Mesozoic rocks by a profound thrust fault that extends across the southern end of Vancouver island.

Resting unconformably upon the Metchosin volcanics and Sooke intrusives, and evidently deposited in deep embayments in these rocks, are sediments of upper Miocene age, the Sooke formation. They once formed an extensive coastal plain, but are now confined to isolated basins fringing the southwest coast of the island.

Mantling the hard rocks are superficial deposits of various kinds, which, although deposited by river, lake, and marine agencies, are composed largely of glacial detritus. They were deposited during the Admiralty and the Vashon epochs of glaciation, and during the Puyallup interglacial epoch. Since the last Glacial epoch, they have been uplifted, retrograded along the shore, and in places covered by recent alluvium.

ECONOMIC GEOLOGY.

Gold occurs in the gravels of the streams which have cut into the Leech River formation, having been derived from small and very low grade quartz veins. The gravels, while of fair grade, occur only in small amount.

Copper occurs in contact deposits, developed in the metamorphosed Sutton limestones near their contact with the intrusive granitic rocks, and in impregnated and replaced shear zones with accompanying quartz veins. The contact deposits and shear zones, except the special Sooke type occurring in shear zones in the Sooke intrusives, are of little value. The Sooke type is, however, of great prospective interest.

Some of the shear zone and contact deposits have been considered as possible sources of iron and sulphur, but it is not probable that they are of value for these substances. A bog deposit of ochreous clay in the Sooke district is of too low grade to be of value as an ore of iron, but may be used in the manufacture of cheap paint.

Coal and oil are sought for in the Sooke formation, but the conditions for their formation in commercial quantities have been very unfavourable.

The crystalline limestones of the Sutton formation furnish excellent material for the manufacture of lime and Portland cement, and for fluxing. Lime has been manufactured at three places, and a Portland cement factory is being built.

The clays of the superficial deposits are suitable for common brick and drain-tile, but are not at present utilized. Sand and gravel also are to be obtained from the superficial deposits.

The traps of the Metchosin volcanics afford abundant material for an excellent quality of crushed stone.

General Character of the District.

TOPOGRAPHY.

A large portion of the area represented by the Sooke sheet and the southern part of the Duncan sheet, is a part of the mountainous, plateau-like region of southern Vancouver island, composed of resistant metamorphic and crystalline rocks, which have apparently been reduced to a nearly smooth surface surmounted, however, by a few hills, then uplifted, considerably dissected, and later glaciated. In the southeastern portion of the area, however, the plateau, or upland surface has been destroyed by erosion, although the region still retains considerable relief. Along the southern coast are remnants of the 'west coast' lowland of Vancouver island, formed by the more rapid erosion of the non-resistant sediments that rest on the metamorphic and crystalline rocks and fringe the 'west coast.' In the southern part of the Duncan map-area and northwestern part of the Sooke map-area, remnants of the uplifted old erosion surface are still preserved and form the plateau, or upland plain, whose even sky-line, broken only by a few rounded hills which surmount it, and by deep steep-walled valleys, is the most characteristic feature of the topography. The elevation of this upland plain is about 1,500 feet in the southeastern portion, but increases rapidly to the northwest to 2,000 feet and then increases more slowly to over 2,500 feet. The conspicuous rounded hills which surmount the upland plain by 400 to 600 feet, range in elevation from 2,184 feet (Empress mountain) in the southeastern part of the district to, 3,102 and 3,180 feet (Survey and Valentine mountains) in the northwestern part of the district.

The valleys which dissect the upland are rather irregularly patterned, but may be grouped into two principal systems, those having a general north-south trend and transverse to the strike of the underlying rocks, and those having a general east-west or northwest-southeast trend, corresponding to the strike of the rock formations. There is only one prominent valley of this latter type. It has been developed in a belt of metamorphic sediments, the Leech River formation, near the southern contact with more resistant volcanic rocks, the Metchosin volcanics, along the boundary of the Sooke and Duncan map-areas. This so-called 'valley,' called the Leech River valley[1], is occupied by the streams of three systems, the divides between which are considerably reduced. The streams which occupy the valley are, from east to west, Waugh and Goldstream creeks flowing east, Wolf creek and Leech river flowing west and east and drained to the south by Sooke

[1]Memoir No. 13, Geol. Survey., Can., 1912, p. 22.

river, Bear creek and the central part of Jordan river drained to the south by Jordan river. The larger valleys, notably the transverse north-south valleys, have been scoured out by valley glaciers, fed from the ice cap which covered the area. They have been considerably widened and in places deepened, in three instances sufficient to form troughs, the two western of which contain Sooke and Shawnigan lakes, while the easternmost is below sea-level and forms the southern fiord portion of the Saanich inlet, known as Finlayson arm. A wide, flat-bottomed valley in the northwestern part of the area is 3 miles long by 1 mile wide, with a small lake at its northern end. It may have held a larger lake, but it is now largely filled with recent alluvium, and is called Jordan Meadows.

The southeastern portion of the area is characterized by numerous well rounded and frequently flat-topped or ridge-like hills whose summits are from 500 to 1,800 feet above sea-level. The hills are separated by irregularly patterned, deep, and frequently broad, drift-filled valleys. The irregular southern shore-line seems to be the result of the depression below sea-level of a surface largely of this type. The lowland areas along the southern coast consist, as stated, of remnants of the once more extensive 'west coast' lowland, formed by the rapid erosion of only slightly disturbed sedimentary rocks, that after a slight recent elevation has been retrograded by wave attack.

CLIMATE AND VEGETATION.

The climate of the region varies rather exceptionally. At sea-level the temperature is uniform and temperate, the average being nearly 40° F. in winter and 55° F. in summer, but on the upland the differences in temperature are, of course, much greater. However, the rainfall varies from 30 to 35 inches a year at sea-level in the eastern part of the region to nearly 100 inches a year at sea-level in the western part of the region. On the upland the variation is not so great, and the rainfall varies from 60 to 90 inches a year. The greater part of the rain falls in the winter months, while the summer is usually dry.

With the exception of the cleared land, virtually the entire area is heavily forested. The principal forest trees are Douglas fir, red cedar, hemlock, and spruce, with some yellow cedar, balsam, and pine. Where the forest is thick the underbrush is usually not very abundant, but in the more open and wetter areas it is extremely thick, and is a great hindrance to travel. It consists of dense shrubs, such as salal, salmon, and huckleberry, and varieties of maple and alder. In the poorly-drained glaciated valleys, high broad-leafed ferns and devil's club abound.

Comparatively little of the land is cleared for agriculture. Only portions of the drift covered areas of the 'west coast' lowland, of the hilly southeastern district, and of the wide glaciated valleys are cultivated to any great extent. Garden vegetables, fruit—chiefly berries—and some grain are the principal products.

MEANS OF ACCESS.

The area, as a whole, is fairly accessible. In the eastern and southern parts are several good roads—trunk roads running north via Mt. Malahat and via Sooke lake, and west to East Sooke peninsula and to Sooke, Otter point, and Jordan river. From these are several branch roads. The Esquimalt and Nanaimo railway crosses the eastern part of the area and the grade of the Vancouver Island line of the Canadian Northern system, which crosses the area a few miles to the west, is almost completed. Access to the Jordan River country is to be had by the railways and roads of the power and timber companies operating in that district. There are also several good trails leading to the less accessible portions, although

some of the upland of the western part of the area is reached by packing trips. The southern coast and the shores of Sooke and Shawnigan lakes are, of course, accessible by boat.

General Geology.

Table of Formations.

Superficial deposits	Quaternary.	
Post-Glacial deposits	Recent.	
Beach, valley, and swamp alluvium.		
Vashon Glacial deposits	Pleistocene, later Glacial epoch.	
Colwood sands and gravels	Stage of glacial retreat.	
Vashon drift	Stage of glacial occupation.	
Puyallup interglacial deposits	Pleistocene, interglacial epoch.	
Cordova sands and gravels.		
Maywood clays.		
Admiralty Glacial deposits	Pleistocene, earlier Glacial epoch.	
Admiralty till.		
Sooke formation	Upper Miocene.	Sandstones, conglomerates, and some shale.
Sooke intrusives	Post-Eocene	Gabbros, anorthosite, and *quartz-diorite.*
Metchosin volcanics	Upper Eocene	Amygdaloidal, and fine-grained basalts, agglomerates and breccias, diabase and basalt porphyrites.
Batholithic and Minor intrusives	Upper Jurassic and possibly lower Cretaceous, correlated with Coast Range batholith.	
Saanich granodiorite.		
Colquitz quartz-diorite gneiss.		
Wark gabbro-diorite gneiss.		
Vancouver group	Jurassic and Triassic.	
Sutton formation	Lower Jurassic and probably Triassic	Lentils of crystalline limestone.
Vancouver meta-volcanics	Lower Jurassic and may include Triassic	Chiefly massive and porphyritic meta-andesites.
Malahat meta-volcanics	Carboniferous?	Massive and schistose dacites and andesites, tuffs, and fine-grained cherty rocks.
Leech River formation	Carboniferous?	Slates, slaty and quartzose schists, and micaceous quartzite, amphibolites and chloritic schists.

GENERAL DESCRIPTION OF FORMATIONS.

Leech River Formation.

Apparently the oldest rocks, not only of the area under consideration but of southern Vancouver island as well, are a series of metamorphic, fine-grained sedimentary rocks with some fragmental volcanics, called the Leech River formation. They underlie a belt 1 to 7 miles wide, widening to the west, that extends across the northeastern part of the Sooke map-area and southwestern part of the Duncan map-area, with a strike of about N. 70° W. The metamorphic sediments consist chiefly of carbonaceous slaty schists, with some true slates and micaceous and quartzose schists, and even micaceous quartzites. There are, in places, especially along the northern boundary of the belt, some metamorphic volcanic rocks now converted to amphibolite and chlorite schists. Some of the quartz-biotite schists also are probably of volcanic origin. The rocks are greatly deformed and have a general strike parallel to the trend of the belt which the formation underlies. The dips are steep, ranging chiefly from 60 to 90 degrees, the prevailing dip being to the north. Sheared and slickensided rocks are common, and doubtless many faults occur. Non-persistent veins and lenses of quartz are exceedingly numerous, and carry small values in gold. Along the northern boundary of the belt the metamorphic sediments of the Leech River formation are transitional into the metamorphic Malahat volcanics. The two formations are conformable, but their contact is fairly definite. To the south, the Leech River rocks are separated from the much younger (upper Eocene) Metchosin basalts by a profound overthrust fault that extends for 40 miles across the southern end of Vancouver island[1]. The Leech River rocks are also intruded by small masses, elongated in the direction of foliation, of quartz diorite or granite gneiss, doubtless referable to the Colquitz gneiss. The rocks are, as mentioned, chiefly of sedimentary but partly of volcanic origin. Their age is doubtful but has been considered provisionally to be Carboniferous[2].

Malahat Volcanics.

To the north of the Leech River formation, and conformable with it, is a series of schistose and chiefly fragmental volcanics, largely of the composition of a dacite. These have been previously mapped and described with the Vancouver volcanics, although the possibility of their being older and conformable with the Leech River sediments was pointed out[3]. On account of their conformability with the Leech River sediments and their dissimilarity to the Vancouver volcanics they have been grouped separately and called the Malahat volcanics, from the district in which they occur most extensively. They underlie an irregular but persistent belt, ranging from 200 feet to 5 miles in width, north of the Leech River formation, extending from Langford lake, east of Goldstream, to west of Jordan Meadows. The rocks consist chiefly of dacite tuffs varying from fine-grained carbonaceous and argillaceous tuffs to coarse grained, sandy tuffs and breccias. There are also some flow rocks, both dacites and andesites. The rocks are prevailingly schistose and many of the fine-grained tuffs are cherty. The rocks have been greatly deformed, having an attitude conformable with the Leech River sediments. They are sheared and slickensided and cut by small veins and lenses of quartz. The northern boundary of the Malahat volcanics is very irregular and is with the Wark gabbro-diorite and the Colquitz quartz-diorite gneisses, which are

[1]See Memoir No. 13, Geol. Surv., Can., 1912, p. 93 and p. 145.
[2]Memoir No. 13, Geol. Survey., Can., 1912, pp. 43-44.
[3]Memoir No. 13, Geol. Surv., Can., 1912, pp. 53-54, p. 56. p. 57, and p. 60.

intrusive into the Malahat volcanics. The age of the Malahat volcanics is doubtful, but since they are conformable with the Leech River sediments, and were apparently formed during a volcanic period which either immediately preceded or directly followed the period of sedimentation, they are provisionally considered to be of the same age as the Leech River sediments, that is, Carboniferous.

Vancouver Group.

Vancouver Volcanics and Sutton Limestones.—Those rocks of the area that are assigned to the Vancouver group, which consists of the lower Mesozoic rocks underlying the larger part of Vancouver island, are the Vancouver meta-volcanics and the Sutton limestones. The Vancouver meta-volcanics consist of metamorphosed basic volcanic rocks, principally meta-andesites, with both flow and fragmental types, the flow types predominating. They occur along the northern part of the area surveyed, extending from Saanich inlet across the north end of Shawnigan lake to Koksilah ridge. They are greatly deformed and are intruded by all of the batholithic rocks, the Wark and Colquitz gneisses occurring to the south of the Vancouver volcanics, and the Saanich granodiorite to the northeast.

The Sutton limestones occur chiefly as lentils of crystalline limestone or marble, intercalated with the Vancouver meta-volcanics, and several of these lentils, up to nearly a mile in length, occur in the belt underlain by the Vancouver volcanics. Six or seven other lentils occur as isolated masses or roof pendants in the batholith of the Wark and Colquitz gneisses. The limestones or marbles of these lentils are identical with those intercalated with the Vancouver volcanics, and are correlated with them, although some, especially one occurring three-fourths of a mile west of the 17th mile-post on the Esquimalt and Nanaimo railway, are more closely associated with the Malahat meta-volcanics.

The Sutton limestones and Vancouver volcanics are in general contemporaneous and conformable, the limestones probably having been built by marine organisms that lived on the shore of the volcanic islands formed during the eruption of the Vancouver volcanics. However, the actual contacts between the two formations are intrusive, the volcanics cutting the limestones. It is possible that the isolated lentils of limestone in the Wark and Colquitz gneisses belong to a lower formation, and perhaps should be correlated with the Nitinat formation, supposed to conformably underlie the Vancouver volcanics[1]. The age of some of the Vancouver volcanics and Sutton limestones is lowermost Jurassic, but they probably include some Triassic rocks[2].

Batholithic and Minor Intrusives.

Intrusive into all the formations described above are batholiths and stocks of granitic rocks and their accompanying dykes. The granitic rocks were irrupted during one general period of intrusion, during and following the deformation of the older rocks, probably in upper Jurassic time, and are, therefore, correlated with the Coast Range batholith of British Columbia[3]. Considered in more detail, however, the granitic rocks may be divided into three types which were irrupted in a definite sequence, as follows: Wark gabbro-diorite gneiss, Colquitz quartz-diorite gneiss, and Saanich granodiorite.

Wark and Colquitz Gneisses.—The Wark gabbro-diorite gneiss and the Colquitz quartz-diorite gneiss are very intimately related and form virtually a single batholith. It extends across the southern part of the Duncan map-area, from the

[1] See Memoir No. 13, Geol. Surv., Can., 1912, pp. 44-50.
[2] Memoir No. 13, Geol. Surv., Can., 1912, pp. 68-71.
[3] Memoir No. 13, Geol. Surv., Can., 1912, pp. 112-113.

Highland district on the east side of Finlayson arm of Saanich inlet, to the headwaters of Koksilah river, north of Jordan Meadows. It has a maximum width near Sooke and Shawnigan lakes of 9 miles, but narrows to nothing to the northwest. A granitic gneiss, probably a facies of the Colquitz gneiss, forms also small bosses and stocks intrusive into the Leech River formation near Goldstream and Jordan rivers. The older type, the Wark gabbro-diorite gneiss, is a fairly typical fine to coarse grained gabbro-diorite, composed chiefly of plagioclase feldspar and hornblende with more or less biotite. The composition varies, in places the feldspar predominating and in other places the hornblende. Although large masses of the typical gabbro-diorite gneiss occur, it is nearly everywhere cut by numerous apophyses of quartz-diorite and quartz-feldspar gneisses, and frequently a complex of the gabbro-diorite and quartz-diorite gneisses has been formed in which the two types cannot be mapped separately. The Colquitz quartz-diorite gneiss also forms lenticular masses, up to 4 or 5 miles in length and 1 mile wide, which are intrusive into the gabbro-diorite gneiss, so that a series of irregular alternating belts of the two rocks is formed.

The Wark and Colquitz gneisses have been dynamo-metamorphosed by movements after their intrusion, but much of their gneissic and sometimes banded structure appears to be primary, due to movements during their intrusion or before they became completely crystallized. They are also considerably altered and fractured.

Saanich Granodiorite.—The youngest granitic rock, the Saanich granodiorite, forms a batholith intrusive into the Vancouver volcanics. The batholith is exposed in the area surveyed only in the northeast portion, in the vicinity of Mill bay and Cobble hill. The rock is light coloured, medium grained, granodiorite, typical of the batholiths of the coast region of British Columbia. It consists essentially of feldspar, orthoclase and andesine, quartz, and accessory hornblende, and usually biotite. It also contains numerous small, rounded segregations, darker coloured than the normal rock, and consisting chiefly of plagioclase and hornblende. The granodiorite, although much less metamorphosed than the Wark and Colquitz gneisses, is considerably altered, greatly fractured, and, in places, somewhat gneissic.

Associated with the granitic rocks, especially with the Saanich granodiorite, are dykes and other intrusive masses. Those associated with the Saanich granodiorite range from diorite to granodiorite porphyrites. Among the relatively few dykes which cut the Wark and Colquitz gneisses, is an augite porphyrite dyke, exposed near the dam of the upper Goldstream lakes. This is of interest in that the rock resembles the augite andesites more or less closely associated with the Sicker series[1].

Metchosin Volcanics.

Underlying the greater part of the Sooke map-area, are the Metchosin volcanics. They are all basic, chiefly basalts and diabase, the latter occurring as dykes in the basalts. The basalts vary from coarsely porphyritic and ophitic varieties to amygdaloids, and frequently exhibit pillow and columnar structures. They are interbedded with fragmental varieties ranging from fine, in places cherty, tuffs to very coarse agglomerates. Some of the fragmental rocks are water-worn and at least one bed of tuff, on the south shore of Albert head near the eastern boundary of the map-area, is fossiliferous. The fossils, which are chiefly gastropods, have been determined by Professor Charles E. Weaver, to be of upper Eocene age, and to be identical with fossils occurring in similar volcanic rocks on the

[1]See Memoir No. 13, Geol. Surv., Can., 1912, p. 52.

Olympic peninsula[1]. From this evidence, the Metchosin volcanics which were previously considered to be doubtfully Jurassic or Triassic, are now known to be of upper Eocene age.

The Metchosin volcanics have been deformed and more or less altered. They have a general northwest-southeast strike and are evidently involved in several folds, although the prevailing dip is about 30 degrees to the northeast. They are extensively sheared and faulted, and their northern contact is the profound thrust fault, which separates them from the Leech River formation. They are also intruded by masses of the Sooke intrusives. The deformation and intrusion must have taken place at or near the close of Eocene time, for they are unconformably overlain by the Sooke formation of upper Miocene age and, farther west, probably by lower Miocene sediments, the Carmanah formation.

Sooke Intrusives.

Intrusive into the Metchosin volcanics are several small masses and stocks, composed chiefly of gabbro. This gabbro has been called the Sooke gabbro[2] from its principal occurrence in the East Sooke peninsula. Since the intrusive masses have a considerable range in composition, their name had best be changed to the Sooke intrusives. Only two stocks were previously known, those of East Sooke peninsula and of Rocky point[3], but during the past field season, five other stocks, their lengths varying from 1 mile to over 5 miles, were discovered. These occur east of Sooke river near Empress mountain, northwest of Sooke harbour at Broome hill, west of Kirby (Coal) creek a mile from the coast, underlying the divide between the upper parts of Muir and Kirby creeks, and to the east of Jordan river 5 miles from the coast. They are irregular in outline but have a general northwest-southeast trend corresponding with the strike of the Metchosin volcanics. Besides the larger stocks there are five or six smaller masses. Also, exposed a few yards north of the 15th mile-post on the Esquimalt and Nanaimo railway, and intrusive into the Malahat meta-volcanics, is a small mass of gabbro that should probably be correlated with the Sooke intrusives.

The rocks composing the Sooke intrusives are, as mentioned, chiefly gabbros, but range to feldspathic gabbros and anorthosites, and to quartz diorites. The gabbros are chiefly hornblendic, although in some facies no hornblende is present and augite and olivine are the essential dark minerals. The feldspathic gabbros, some facies of which consist essentially of feldspar alone and are classed as anorthosites, and the quartz diorites are clearly differentiates of the gabbro. They occur as satellitic masses associated with the normal gabbros, clearly intrusive into the normal gabbros in some places. In other places the two contrasting "acid" and "basic" types are transitional, and in one locality to the south of Empress mountain the more acid feldspathic gabbros and quartz diorites clearly overlie and grade downward into normal gabbro.

With the probable exception of the mass intrusive into the Malahat volcanics near the 15th mile-post on the Esquimalt and Nanaimo railway, the Sooke intrusives are intrusive only into the Metchosin volcanics. They are, therefore, younger than upper Eocene and were probably irrupted during or directly following the deformation of the Metchosin volcanics in post-Eocene time, since both are

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[1]Arnold, Ralph—Reconnaissance of the Olympic Peninsula: Bull. Geol. Soc. Am., vol. 17, 1906, pp. 460-461.

Weaver, Charles E.—Preliminary Report on the Tertiary Palæontology: Bull. No. 15, Washington Geol. Surv., 1912, pp. 12-14.

[2]Memoir No. 13, Geol. Surv., Can., 1912, p. 113.

[3]Neither of these was studied during the field season of 1912. They are rather fully described in Memoir No. 13, Geol. Surv. of Can., 1912, pp. 113-124.

unconformably overlain by the upper Miocene sediments of the Sooke formation. The rocks while sheared and metamorphosed and mineralized in places, are, as a rule, not greatly altered, and are in great contrast to the upper Jurassic granitic rocks. On the east Sooke peninsula, where the metamorphism has been most intense, there are extensive shear zones in the gabbro masses, which have been replaced by sulphides of iron and copper, and on these have been located the most promising copper prospects of the region.

Sooke Formation.

In the Sooke map-area, fringing the southwestern coast of Vancouver island, are marine sediments of upper Miocene age, the Sooke formation. They occur in isolated basins separated by ridges of the Metchosin volcanics and the Sooke intrusives, upon which they rest unconformably, and are apparently remnants of a once more extensive coastal plain, the ridges of the Metchosin volcanics and Sooke intrusives having been promontories between which the sediments were deposited. The larger basins occur north of Sooke harbour and north of Sooke bay, underlying the lower portions of the Muir Creek and Kirby (Coal) Creek valleys. Three small basins occur along the coast west of Sherringham point, and there are several outliers of the Muir and Kirby Creek basins, near the main basin.

The sediments consist chiefly of sandstone and conglomerate with thin beds of sandy shale and marl. The basal conglomerates, composed of boulders of the Metchosin volcanics and Sooke gabbro, are usually very coarse, and rest on an uneven erosion surface. In places, there are thin seams of lignite, usually 1 to 2 inches thick, but occasionally, as near the bridge crossing Kirby (Coal) creek, nearly a foot in thickness. Thin, cigar-shaped lenses of lignite also are found. The sediments are but slightly deformed, the individual basins having a broad synclinal structure, with a general pitch to the southwest. The beds are, however, broken by rather numerous faults, usually normal faults with a displacement of only a few feet. The average thickness of the sediments in any one basin is probably not more than 500 or 600 feet, but the maximum thickness, as shown by the bore-hole near the mouth of Muir creek, is over 1,500 feet[1], showing that the sediments must have been deposited in old, deep embayments in the Metchosin volcanics and Sooke intrusives.

Superficial Deposits.

A large part of the area is covered by superficial deposits of various kinds. These have been classified, as shown in the table of formations, and as far as possible have been mapped separately. They will, however, be only briefly described here[2]. They were deposited by different agencies during the various stages of glacial occupation and retreat, the map-areas having been twice over-ridden by glaciers. Little remains of the Admiralty till deposited by the earlier glaciers. On the retreat of the earlier glaciers the Puyallup interglacial deposits were formed, in part below sea-level, and they now occur below elevations of 300 or 400 feet. They consist of stratified clays, sands, and gravels. In general, the clays occur near the base and the sands and gravels near the top, and hence the deposits are subdivided into the Maywood clays, and the Cordova sands and gravels. The interglacial deposits were partially eroded during the later but less intense period of glaciation, the Vashon. During this period the Vashon drift was formed largely

[1] Previously given by the writer as 500 to 700 feet. Memoir No. 13, Geol. Surv., Can., 1912, p. 139.

[2] For a more complete description of the deposits, see the writer's Geology of the Victoria and Saanich map-areas, Memoir No. 36, Geol. Surv., Can., 1913.

by ice alone but in part by water. The Vashon drift is ordinarily an unsorted till, but in places is rudely stratified. It forms a mantle a few feet thick covering the hard rocks and the interglacial deposits, and is the most extensive of the superficial deposits. During the retreat of the Vashon glaciers, delta deposits of coarse sands and gravels, the Colwood sands and gravels, were formed at favourable places at the front of the larger retreating valley glaciers. Since the Glacial period, alluvium has been deposited in lakes and swamps which formed in the poorly-drained hollows of the drift mantle and in dammed glaciated valleys. In places along the shore the superficial deposits have been retrograded to form steep cliffs, and beaches, spits, and bars have been built of the retrograded material.

Economic Geology.

The mineral resources of the area have already been rather fully described[1] and only need to be briefly summarized here, especially since little field work was done on them during 1912, and since little development work has been done since the writer's previous examination.

GOLD.

Gold occurs in the gravels of the streams which drain the area underlain by the Leech River formation, having been derived from the very low grade quartz veins which traverse that formation. The gold-bearing gravels are usually of fair grade, but occur in small amounts. In the 'sixties,' the deposits in the Leech and Jordan rivers were discovered and worked, the yield being estimated at from $100,000 to $200,000. For a number of years, Chinamen have worked on Leech river, and one or two more extensive but unsuccessful attempts have been made recently to obtain gold from Leech river and its north fork. Some of the quartz-feldspar veins which were formed during the intrusion of the granitic rocks have been prospected for gold, entirely without success, and it is not probable that they contain gold in commercial quantities.

COPPER.

The copper deposits may be subdivided into two types—contact deposits, and impregnated and replaced shear zones with accompanying quartz veins. The contact deposits are developed in the metamorphosed Sutton limestones near their contact with the intrusive granitic rocks. The principal deposits of this type occur on Mt. Malahat, east of Shawnigan lake, where the limestones are little more than large inclusions in the Wark gabbro-diorite gneiss near later intrusives of the Colquitz quartz diorite. The deposits occur in irregular masses, not more than 8 or 10 feet wide, usually more or less elongate, and rudely lenticular. They consist of magnetite, pyrrhotite, and pyrite, with disseminated grains and veinlets of chalcopyrite. There has been no commercial production from them, and they appear to be too small and of too low grade to be probable sources of copper ore in the near future.

Throughout the Vancouver and Malahat meta-volcanics are sheared zones more or less mineralized, chiefly with pyrite and chalcopyrite. Pyrrhotite and magnetite are also present. Associated with the mineralized shear zones are small veins and lenses of quartz which frequently contain chalcopyrite and other metallic minerals. The principal occurrence of this type of deposit is on the south slope of Mt. Skirt, a mile to the northeast of Goldstream station, in the schistose

[1] Clapp, C. H., Memoir No. 13, Southern Vancouver Island: Geol. Surv., Can., 1912.

Malahat volcanics. Mineralized shear zones occur also in the Metchosin volcanics, but are not numerous except near the intrusive stocks of Sooke gabbro. There has been no commercial production from the deposits described above, and considering the low grade tenor of the ore, and the irregular character of the deposits, they are in most instances improbable sources of copper ore.

In the Sooke gabbro are wide shear zones, which have been impregnated and partly replaced by chalcopyrite and by pyrite, pyrrhotite, and magnetite. This type having many characteristic features, and being more important than any of the other shear zone deposits, has been described separately as the Sooke type[1]. The deposits are best known and presumably best developed on the East Sooke peninsula, but no field work was done there during 1912. The following summary description is from Memoir No. 13, Geological Survey, Canada, p. 174:—

> Pyrite, pyrrhotite, and magnetite occur chiefly in large masses which are composed almost entirely of metallic minerals. Chalcopyrite occurs chiefly in wide shear zones, through which it is disseminated as small patches. lenses, or veinlets, The only important gangue mineral is hornblende. Since the chalcopyrite is usually disseminated through wide zones of sheared rock, the deposits are of low grade. The ore mineral could, however, be easily concentrated, hence the deposits are of great prospective value.

It was found during the past season that the Sooke gabbro stocks, previously thought to have been intruded in upper Jurassic time, were intruded in post-Eocene time and hence the mineral deposits are known to be comparatively young. It is probable, therefore, that they have suffered but comparatively slight erosion, and hence probably continue to greater depths than if they were of upper Jurassic age. It was also found during 1912 that there is a greater number of the Sooke gabbro stocks than was previously supposed[2], and the larger of these are well worth prospecting.

IRON, PIGMENTS, AND SULPHUR.

The replacement or segregation deposits which occur in the Sooke gabbro, and which consist of massive pyrrhotite, magnetite, pyrite, and chalcopyrite, have been exploited as sources of iron ore. Since the chief mineral of these deposits is pyrrhotite, although magnetite is present in considerable quantity, the deposits are unlikely sources of iron ore. In the Sooke district, in the vicinity of Demaniel river, is a bog deposit of yellow ochreous clay, which has been mentioned as a source of iron ore, but since the material contains only 15·3 per cent of iron it is of too low grade for an iron ore. It is, however, suitable for cheap paint. Farther west some of the contact deposits are fairly large and composed chiefly of magnetite. These are of prospective importance, but none of the contact deposits in the area under consideration are large enough or rich enough in magnetite to be considered as a possible source of iron ore.

The massive sulphide deposits in the Sooke gabbro, and those contact deposits which are rich in sulphide minerals are possible but not probable sources of sulphur.

FUEL: COAL AND OIL.

The Sooke formation along the southwest coast has been considered as a possible source of coal and oil, and has been prospected at Sooke, Muir creek, and Kirby (Coal) creek. The only indications of coal are thin seams of lignite and

[1] See Memoir No. 13, Geol. Surv., Can., 1912, pp. 174-180.
[2] See description under General geology, Sooke intrusives.

lignitic sandstones, with occasional cigar-shaped lenses and cylindrical masses of lignite. The Sooke formation consists largely of coarse detritus, which was deposited rapidly off a rather mountainous coast under marine conditions. These conditions are very unfavourable for the formation of coal. It seems as if the carbonaceous matter present was largely of drift origin; that is, composed of logs and other vegetable waste, which accumulated along the shores of the Tertiary ocean during the deposition of the Sooke formation. The small seams of lignite that occur are very impure, the following being an analysis of the thickest seam known, 8 inches thick, exposed on Kirby (Coal) creek, near the Jordan River road bridge. The sample was collected by W. L. Uglow and was analysed in the laboratory of the Mines Branch, Department of Mines.

Water	7·70
Vol. combustible	29·37
Fixed carbon	23·11
Ash	39·82
	100·00

In the Sooke formation there is no thick shale horizon rich in organic matter from which oil might have been derived, although some of the sandstones contain large numbers of marine organisms, from which the small amount of oil forming insignificant seepages, has probably been derived. Since the rocks are coarse grained and porous, without impervious layers, and not folded, but broken by many small faults, the structural conditions are unfavourable for the accumulation of oil. Also the individual basins of the Sooke formation are small, and the thickness of the rocks, except locally, is probably less than 500 or 600 feet. It is, therefore, with a great deal of assurance that any extensive attempt at prospecting for coal and oil in the Sooke formation is discouraged.

LIME, CEMENT, AND FLUXES.

The Sutton limestones furnish excellent material for the manufacture of lime and Portland cement, and for fluxing. They are, as a rule, pure, low in magnesia and insoluble material, and virtually free from phosphorus. Sulphur in the form of pyrite is in variable amount, but in the less altered varieties is usually low.

The following is a partial analysis by Mr. H. A. Leverin, Mines Branch, Department of Mines, of a sample collected by the writer from the old limeston quarry, one mile west of Raymond crossing, Shawnigan district.

Calcium carbonate	93·12
Magnesium carbonate	0·96
Ferric oxide and alumina	2·00
Insoluble mineral matter	1·80

The limestones have been quarried for the manufacture of lime 2½ miles northeast of Goldstream in the Highland district, west of Raymond crossing in Shawnigan district, and on the west shore of Saanich inlet, 5 miles south of Mill bay. At present they are quarried only at the last locality. Here a large plant is being built to manufacture Portland cement.

CLAYS.

Only the clays of the superficial deposits occurring chiefly in the Maywood clays, are suitable for use as commercial clay. The clays occur in beds up to 10 or 15 feet thick. They are chiefly sandy, with numerous pebbles and boulders, but

are fairly plastic and are of low fusibility. They are not at present utilized, although they are similar to those in the vicinity of Victoria which are used extensively for common brick and drain-tile, and in the manufacture of Portland cement.

SAND AND GRAVEL.

The sands and gravels of the superficial deposits, especially the Colwood sands and gravels, are of good quality and very abundant. At present they are quarried in the map-area only near the Esquimalt and Nanaimo railway, east of Langford lake, for railway ballast, and on the west shore of Saanich inlet; but farther east, in the vicinity of Victoria, the same kind of deposits are quarried extensively.

STONE.

The fractured and sheared character of most of the rocks renders them unfit for building purposes. However, the traps, especially those of the Metchosin volcanics, offer abundant material for an excellent quality of crushed stone. There is no rock quarried at present, except to the east of the map-area, on Albert head.

GEOLOGICAL SECTION ALONG THE GRAND TRUNK PACIFIC RAILWAY FROM PRINCE RUPERT TO ALDERMERE, B.C.

(*R. G. McConnell*)

General Physical Features.

The region traversed by the Grand Trunk Pacific railway from Prince Rupert to Telkwa, was practically unknown, until recent years, except to the fur trader, prospector, and an occasional explorer, and even at present, surveys are practically limited to the main waterways, and only the general geological features have been ascertained. The district includes the Coast range and a portion of the mountainous interior region bordering it on the east, and bold relief is the dominant feature everywhere.

The Coast range, where crossed, has a width of about 60 miles and, with the exception of some included schists, is everywhere carved out of coarse granitoid rocks. The mountains in the immediate vicinity of the Skeena valley are not high, seldom exceeding 5,000 feet. They are as a rule densely forested below, and steep and craggy above, but have been toned down by the moving ice of the Glacial period and rendered somewhat monotonous. Higher, partially snow-covered, and more impressive peaks, are occasionally seen up tributary valleys. Small glaciers of the Alpine type occur at a few points, but do not descend to low levels.

The eastern boundary of the Coast range is not always easy to define, as it often merges insensibly into the high plateaus and mountains of the interior. On the Skeena, the main range is bordered on the east by a wide depression occupied north of the Skeena by the Kitsumgallum river. This great trench, 4 to 5 miles wide in places, extends northward to the Nass and southward across the Coast range, reaching the sea at the head of Kitimat arm. It evidently represents an old, partially abandoned, valley of erosion possibly robbed by the Skeena.

East of the Kitsumgallum valley a second wide range of high, nameless mountains, mostly built of schist and granite, is crossed. These connect to the south with the Coast range, and may be considered a spur from it. After passing them the dry interior district is reached, and a change in the topography is immediately noted. The valleys of the Skeena and its tributaries become much wider, are frequently terraced, and the relief is expressed in long even ridges, or in isolated groups of high peaks, mostly built of upturned Jurassic and Cretaceous strata surrounding granite cores. Among the prominent groups are the Rocher Déboulé at the confluence of the Skeena and Bulkley rivers, some peaks of which reach elevations of over 8,000 feet, and judging from their rugged angular character evidently exceeded the limits of glaciation, and the lofty Hudson Bay mountains bordering the Bulkley on the southwest.

The Skeena river, which is followed by the railway from its mouth eastward through the Coast range to its junction with the Bulkley, heads in some of its branches with the Fraser, and, like it, drains a large portion of the rough elevated country lying between the Coast range and the Rocky mountains. It is a wide, swift-flowing stream, repeatedly dividing around low alluvial islands in its passage through the Coast range. In its upper reaches it becomes more confined and its course is interrupted by numerous short boulder-strewn rapids and by occasional canyons. It is ascended by river steamers to Hazelton at the mouth of the Bulkley, a distance of 154 miles, but its navigation, except near the mouth, is difficult and dangerous.

The valley of the Skeena, where it cuts the Coast range, is a deep, steep-sided trough, precisely similar to the fiord-like depressions filled with salt water so prevalent along the coast. It has, however, been gradually silted up by the river down to about mile-post 40, and is bottomed with alluvial flats and islands. Above the mouth of the Kitsumgallum its character changes. The valley above this, at the end of the Glacial period was floored for some distance by estuarine, and farther up by glacial deposits, and in place of depositing its load the river is scouring out, and along most of its course is sunk in a secondary valley.

The secondary valley is mostly in drift, but along considerable stretches it cuts through these loose deposits down into the bed-rock beneath, and contracts into a canyon. The rock-walled portions are due, in part at least, to deviations of the stream from the lowest portions of its pre-Glacial channel. Some of them may owe their origin to small post-Glacial uplifts.

The Skeena valley, east of the semi-crystalline rocks which border the Coast Range batholith on that side, enters a more easily eroded region, where it gradually expands in width, and the bordering slopes become much less regular.

The Bulkley river, which is followed after leaving the Skeena, is a wild, unnavigable stream, plunging over rapids or crowding through canyons along its whole course. The enclosing valley is very large, its width ranging from 4 to nearly 10 miles. It is bordered on the southwest, from the Skeena to Moricetown, by the high rugged Rocher Déboulé mountains, and from Moricetown to the Telkwa by the almost equally rough Hudson Bay mountains. On the northeast the bounding elevations are low and more even, seldom breaking into prominent peaks.

The valley is heavily drift covered, and a cross section usually shows a central terraced portion, bordered by uneven slopes, leading up to the bounding ridges and mountains. The river is sunk in a secondary, and for long reaches, rock-walled valley from Hazelton to Telkwa.

The grade of the Skeena from Essington, where the current practically ceases, to Hazelton, a distance of 154 miles, averages 4·2 feet per mile, and that of the Bulkley from Hazelton to Telkwa, a distance of 58 miles, 17·1 feet per mile. The elevation at Telkwa is 1,650 feet above sea-level.

Natural Resources.

The principal natural resources of the district consist, on the coast, of fisheries and the product of the forest, and in the interior of agriculture and mining.

The Skeena is a noted salmon river, and the fishing industry has been established on a firm basis for some years, and is still growing. The product of the numerous salmon canning establishments, located on islands off the mouth of the Skeena, and along the mainland, is very large, in favourable seasons exceeding 200,000 cases. Other fishes of commercial importance are the cod, herring, oolachan, and, farther away, near the Queen Charlotte islands, the halibut.

The Coast district is forested, practically everywhere, up to a height of about 4,000 feet above sea-level. The principal forest trees along the lower part of the Skeena are the hemlock (*Tsuga mertensiana*), the stately Sitka spruce (*Picea sitchensis*) specimens of which frequently attain diameters of from 6 to 8 feet, and the white fir (*Abies grandis*). The cottonwood (*Populus trichocarpa*) is well represented along the lower flats. Less common trees are the valuable yellow cedar (*Chamaecyparis nootkatensis*), and the red cedar (*Thuya gigantea*).

The area of land available for agriculture is very limited near the coast, but the country east of the Coast range, although generally rough and mountainous, contains a number of large areas suitable for this and kindred purposes. Among the most important of these are: the wide longitudinal depressions which follow the Kitsumgallum and Kitwancool rivers from the Skeena north to the Nass, the

benches along the upper Skeena, and the great terraced valley of the Bulkley. Production as yet is small because settlement has barely commenced. It includes small fruits and apples in the valley of the Kitsumgallum, and roots and hardy cereals farther inland.

The mining industry is also in its initial and experimental stages, but promises a rapid development. The scope of the work did not include an examination of the numerous metalliferous discoveries in the neighbourhood of Hazelton and at other points along the route, and the only economic work done consisted in the examination of a reported salt well near Kwinitsa, 44•9 miles east of Prince Rupert.

The conditions found here proved interesting and somewhat peculiar. The mountains in the vicinity of Kwinitsa recede from the river, forming a basin about a mile wide and a mile and a half long, through which the Kwinitsa, a small stream, flows to join the Skeena. The basin has been filled up with sands, clays, and gravels to a level about equal to that of the highest tides which affect the Skeena at this point. About half a mile north of the river, and near the granite rim of the basin, brackish surface water was discovered by Mr. D. C. Whiteford, and on digging down a strong brine was found. The surface is covered with 6 to 8 feet of silty clay, underlain by gravel. The brine occurs in the latter. Several test holes have been put down in the immediate vicinity of the original discovery, but no attempt has so far been made to ascertain the extent or thickness of the brine saturated gravels.

The brine is considered to be imprisoned sea water, somewhat concentrated. At the present time, the water of the Skeena at the mouth of the Kwinitsa, although affected by the tides, is fresh, but at the close of the Glacial period, the Skeena valley here and for a long distance inland, was practically an arm of the sea filled with salt water. Since then, the land has risen, and the sea receded. In the slow recession, conditions at the Kwinitsa basin must have been favourable for the retention of the salt water and its partial evaporation, and the process may have been repeated more than once.

A test of the brine at the Provincial Bureau of Mines, Victoria, gave the following results:—

Sodium chlorite	2823	gram. per imperial gallon.
Mag. sulphate	709	" " " "
Calcium chloride	157	" " " "
Potash (none)	——	
Silica (none)	3·689	" " " "

This does not indicate much concentration, as in Vol. 1 (Physics and Chemistry), page 41, of the records of the Challenger Expedition, the total solids in sea water is given at 34•797 parts per thousand, equivalent to 2435•74 grams per gallon. Only the surface of the gravels, here underlying silts soaked with fresh water, has been tapped, and there is a possibility that denser solutions may be found at greater depths. A small experimental evaporating plant consisting mainly of two galvanized iron pans in which the brine is heated, has been put up and some salt produced. Mr. Whiteford, the owner, claims a yield of one pound of salt per gallon of brine, and is confident the brine can be reduced at a profit. There is a large demand for coarse salt in the neighbourhood, in connexion with the extensive fishing industry at the mouth of the Skeena.[1]

[1] Since this description was written a small bore-hole has been put down by Mr. Whiteford near the centre of the basin. This passed through a few feet of silt and gravel at the surface, then penetrated 200 feet of bluish clay stated to be fossiliferous. Below the clay a hard band made up partially or wholly of rock salt was encountered. Unfortunately the drill used reached its limit at this depth and neither the thickness nor purity of the saline bed was ascertained. Mr. Whiteford intends putting down a second larger bore-hole at once to test these points. It is probable, now, that the surface brine first discovered, represents seepage upwards along the granitic rim of the basin from the saline beds underlying the clay.

Geology.

The formations traversed along the railway route from Prince Rupert to Telkwa include the granitoid rocks and included schists of the Coast Range batholith, bordered on the west by altered sedimentaries, and on the east by a complex of partially altered volcanics. The latter are overlaid and succeeded eastward by a wide belt of middle Mesozoic, mostly tufaceous, rocks, intruded at numerous points by granitic stocks.

A marked feature of the section is the preponderance along it of rocks of igneous origin, both intrusives and extrusives being widely represented.

The rocks have been subdivided into the following groups:—

SEDIMENTARIES AND VOLCANICS.	
Lower Cretaceous	Skeena formation.
Jurassic, possibly including some Lower Cretaceous	Hazelton group.
Triassic?	Kitsalas formation.
Upper Palæozoic?	Prince Rupert formation.
INTRUSIVES.	
Jurassic to Lower Cretaceous	Coast Range batholithic rocks.
Post-Lower Cretaceous	Granodiorite stocks, east of Coast range.

Skeena Formation.

The rocks of this formation occupy isolated basins folded in with those of the Hazelton formation, and resting apparently conformably, or nearly so, on them. The exact relationship has not been worked out. The varieties commonly present are feldspathic sandstones, conglomerates, hardened clays, shales, usually more or less carbonaceous, and occasional seams of coal. The beds are less indurated than those of the underlying Hazelton formation, are seldom fractured, and usually undulate in open folds.

The shales are plant-bearing in places. A small collection made by W. W. Leach, and reported on by Dr. Penhallow, contained the following species:—

Sequoia rigida, Heer.
Thuya cretacea, (Heer) Newberry.
Thyrsopteris sp.

These species indicate an age equivalent to the Kootenay or lowest Cretaceous.

Hazelton Group.

The beds of this formation overlie the semi-crystalline Kitsalas formation at mile-post 123 on the railway, and they are the principal rocks exposed along the Skeena and the Bulkley rivers up to Telkwa, the terminal point of the examination.

The Hazelton rocks are mostly tufaceous in origin, but, unlike those of the Kitsalas, they are well bedded and banded, and are seldom much altered except in the immediate vicinity of intrusive masses. The predominating variety is a heavily banded, bluish grey, rather even-grained rock, made up of minute rock fragments usually andesitic in character, with some broken feldspar crystals and occasional angular grains of quartz. Dark argillaceous beds and bands alternate with the tuffs and tufaceous sandstones. These are usually more or less carbonaceous, and in places, carry thin streaks of coal. Conglomerates, made up of well rolled greenstone, occasionally granite and slate, pebbles in a tufaceous cement also occur, but are not common.

The Hazelton tufaceous rocks, while probably mostly deposited in shallow water, were occasionally built up on land. North of Porphyry creek, a heavy band in the series is made up of a confused mass of grey tuffs, which grade into fine and coarse breccias holding numerous rounded andesitic bombs often 2 feet or more in diameter. In portions of the region, especially from Moricetown southward along the Hudson Bay mountains, the fragmental volcanics are interbanded with rocks, mostly green, occasionally red, andesites.

No complete section across the basin occupied by the Hazelton rocks has so far been made. The thickness is consequently unknown, but it is estimated to exceed 4,000 feet. The beds and associated andesite sheets are occasionally flat, or nearly so, for short distances, but are usually compressed into open, more rarely close, folds, and in places are strongly contorted. Faults are numerous, and in most of the sections the rocks are fissured and traversed by small calcspar veinlets.

Large veins, important for their metalliferous contents, chiefly silver-bearing galena, blende and chalcopyrite, occur in the formation. Several of these are now being explored.

The range in age of the Hazelton formation has not been definitely established. Fossil plants occur in a number of the shaly bands, and a few shells, usually imperfectly preserved, have been collected at several points. These indicate an age ranging from Jurassic up to Lower Cretaceous.

Collections of fossils, made by W. W. Leach from the upper part of the formation and reported on by Lawrence Lambe, include the following specimens:—

Belemnites skidegatensis, Whiteaves.
Nerinea maudensis, Whiteaves.
Pleuromya papyracea, var. *carlottensis*, Whiteaves.
Astarte carlottensis, Whiteaves.
Trigonia dawsoni, Whiteaves.
Inoceramus concentricus, Parkinson.
Pecten (entolium) lenticularis, Whiteaves.
Pecten carlottensis, Whiteaves.
Thracia semiplanata, Whiteaves.

Kitsalas Formation.

The Coast Range batholith is bordered on the east along the Skeena river by a wide belt of volcanics associated with some sedimentary rocks, which have been grouped together as the Kitsalas formation. They are repeatedly intruded by granitic dykes and stocks, and in places are somewhat schistose, but the alteration is nowhere so complete as in the rocks flanking the batholith on the west. Ordinarily, they are greenish to purplish massive rocks, spotted with large, rounded, and irregular areas of epidote, and lined along fracture planes with the same mineral.

The formation is made up near the batholith, of porphyrites, tuffs, and coarse fragmentals, welded closely together, and seldom showing traces of bedding or banding. Farther to the east, the volcanics alternate with dark and light grey, micaceous sedimentaries. The rocks are everywhere highly altered, in places to such an extent as to obscure their origin, but are seldom conspicuously schistose, except along fracture zones.

The age of the old volcanic complex, represented by the Kitsalas formation, is uncertain. It is older than the Coast Range batholith and is placed tentatively in the Triassic.

Prince Rupert Formation.

The Coast range in the vicinity of Prince Rupert is flanked on the west by a wide band of metamorphic rocks, for which the name Prince Rupert formation is proposed. These rocks, originally, were mostly argillaceous, siliceous, and calcareous sediments, but have been intensely altered and converted into mica, quartz-mica, and hornblende schists, and crystalline limestones. Occasional areas of diorite or gabbro, intruded prior to the folding of the region, are now represented by coarse hornblende schists. West of Prince Rupert, in the western part of Digby island, green chloritic and hornblende schists, derived from fragmental and massive volcanic rocks, occur interbanded with the dark grey, sedimentary schists.

In the section exposed along the railway from Prince Rupert eastward to the western edge of the Coast Range batholith, the limestones and crushed volcanics are absent, and the principal variety is a moderately coarse, well crystallized, quartz-mica schist, made up mostly of biotite and angular quartz grains, arranged in alternating lines and narrow lenses. Some carbonaceous dust is also usually present, and pyrite and garnet are common secondary minerals. In places, there is an alternation of dark grey and light grey bands, the former representing the more micaceous, and the latter, the more siliceous varieties. The degree of crystallization also varies, the rocks ranging from phyllites to fine-grained gneisses.

Approaching the granitic batholith there is no notable increase in the crystallization, or in the quantity of secondary minerals present, but aplitic dykes become more common and in the last sections seen, the rocks frequently have a striped appearance due to the intrusion of small acid dykes along the bedding planes, and to the silicification of layers of the schists.

The Prince Rupert schists east of Prince Rupert, have a uniform easterly dip of 30 to 70 degrees towards the granitic batholith, and a north-northwest strike approximately parallel to the western edge of the batholith. West of Prince Rupert, on Digby island, the structure is more complicated and has not been worked out in detail. The tilting and folding of the beds and the crystallization of the sediments in part, at least, as first explained by Spencer[1] and confirmed by subsequent observers, probably preceded the granitic invasion.

The age of the schists, while not definitely known, is probably upper Carboniferous, some confirmatory fossil evidence having been obtained by F. E. and C. W. Wright[2] in corresponding rocks farther to the north in southeastern Alaska.

Coast Range Batholithic Rocks.

The belt of granitoid batholithic rocks which follows the mainland coast of British Columbia and Alaska continuously for nearly 150 miles from Fraser river north to latitude 61° N., has a width, where crossed by the Skeena river, of 58 miles. This long granitic mass, formerly considered to be the product of a single linear invasion, is really made up of a number of batholiths separated in age by considerable time intervals. The intrusions commenced in the Jurassic, and on the evidence of bordering satellitic stocks, probably continued into Lower Cretaceous.

The rocks represented in the line of batholiths range from acid granites to gabbros. The prevailing variety is a grey, medium grained, usually massive, but occasionally coarse, gneissoid rock, intermediate in character between the diorites and granites, and classed generally as a granodiorite. Inclusions of fragments and even large areas of the intruded rocks are common in them.

[1] Spencer, A. C., U.S. Geol. Surv., Bull. No. 287, 1907.
[2] Wright, F. E. and C. W., U.S. Geol. Surv., Bull. No. 347, 1908.

Along the Skeena river, the Coast Range section is made up of wide bands of light and dark grey granodiorites, alternating with bands of dark basic schists, the largest 6 miles across. The granodiorites in this section show a more or less pronounced gneissic structure everywhere. Along their western margin the schistosity conforms generally in dip and strike with that of the bordering, easterly dipping, altered sedimentaries. Farther on, the direction and angle of dip varies from point to point, and in a few places the lines of schistosity are sharply plicated. The gneissic structure is considered to have been assumed during the cooling of the granitic magma, and not to be a product of subsequent dynamic deformation.

In the Skeena section there is no clear evidence of more than one period of intrusion, and the granodiorites, except for slight differences in coloration and an occasional banded arrangement due to a concentration of the dark minerals, have a very uniform character across the range. They are medium to coarse grained rocks, occasionally showing a porphyritic texture, made up of a plagioclase feldspar (usually andesine), orthoclase, microcline, quartz, and either or both biotite and hornblende. Apatite, titanite, and magnetite are common accessories, and epidote and, less frequently, pyrite and garnet are conspicuous secondary minerals. The following table by F. E. and C. W. Wright[1] shows the mineral composition of the average batholithic rocks in the Coast range in southeastern Alaska:—

Quartz	19·4
Orthoclase	6·6
Andesine (Ab_{56} An_{44})	47·4
Hornblende	7·6
Biotite	11·6
Apatite	0·6
Magnetite	0·9
Pyrite	0·1
Titanite	1·3
Epidote	3·5
Chlorite	0·1
Calcite	0·1
Kaolin and muscovite	0·8
	100·0

This rock is more closely related to the diorites than the granites, and might appropriately be called a quartz diorite or tonalite.

The basic bands included in the granodiorites are made up mostly of dark micaceous and hornblendic schists and fine-grained gneisses. They are considered to represent unabsorbed, in places partially absorbed, portions of the intruded rocks, but have been so intensely altered and completely recrystallized that all traces of their original character have disappeared. They often alternate with, or are cut across by bands of, granodiorite, and in some instances have a brecciated appearance due to the number of granitic, aplitic, and pegmatitic dykes crossing them in all directions. Near the basic areas, the granodiorites are usually strongly and regularly banded, the dark bands closely resembling varieties of the included schists.

The basic schists dip at various angles, but in one area are nearly horizontal. The direction of schistosity conforms, as a rule, with that of the enclosing gneissic rocks.

Aplitic and pegmatitic dykes occur everywhere cutting both the granodiorites and the included schists, but are especially abundant along the western margin of

[1] Wright, F. E. and C. W., U.S. Geol. Surv., Bull. No. 347, 1908.

the range. The pegmatite dykes are often of large size, and, as a rule, are very coarsely crystalline. The ordinary constituents are white orthoclase, light pink microcline, quartz, and dark and white mica. Secondary garnets are occasionally present. It is noteworthy that the acid dykes, although belonging to the closing stages of the intrusion, are nowhere schistose themselves. In the western portion of the range they usually cut the schistose granodiorites almost at right angles.

Small basic dykes, younger than the aplites and pegmatites, occur in the range, but are nowhere plentiful in the Skeena section. The common varieties are diabases and hornblende lamprophyres.

Intrusives East of the Coast Range.

The volcanic and sedimentary rocks bordering the Coast Range batholith on the east up to and including the Skeena formation, are repeatedly intruded by stocks, some of large size, very similar in mineralogical composition to the batholithic rocks, and classed generally as granodiorites. The ordinary variety is a greyish, medium grained, massive rock usually granular in texture, but often becoming porphyritic. Dark diorite and light coloured acid porphyritic phases are not uncommon.

These stocks probably belong to the closing stages of the prolonged period of vulcanism in which the long Coast Range group of batholiths was intruded. They cut rocks of Lower Cretaceous age, but are not known to intrude the overlying Tertiary rocks.

Glacial and Post-Glacial Deposits.

The district at the height of the Glacial period was covered everywhere up to an elevation of about 6,000 feet, by a great confluent ice sheet. The general movement of the ice east of the Coast range was southerly, but a huge stream, as shown by numerous strong groovings along the mountain slopes, poured westward to the sea down the valley of the Skeena.

At the close of the Glacial period, the district was depressed, and Skeena valley was occupied by a long arm of the sea which extended through the Coast range into the interior region. Since then there has been a gradual elevation of at least 500 feet, the sea has retreated and the mouth of the river has progressed steadily down the valley.

The deposits, illustrative of these changing conditions, consist of boulder clays, estuarine clays, sands and gravels, and fluviatile sands and gravels.

The boulder clays in the lower portion of the valley have been largely destroyed or buried, up to mile post 160, a short distance below the mouth of the Kitsequecla river. Above this point, the valleys of both the Skeena and Bulkley are covered with a nearly continuous, irregular sheet, thinning out on the ridges and deepening in the depressions. In places, the sheet attains a thickness of over 200 feet. The common variety is dark in colour, exceedingly plastic, and thickly packed with scratched boulders and pebbles.

The boulder clays are often overlaid and underlain, and more rarely interbanded, with stratified clays, sands, and gravels.

The estuarine deposits, mostly dark, plastic, stratified clays with associated sands and gravels, have been largely destroyed along the valley of the Skeena, and occur only in isolated patches. No fossils were found in them, but similar beds, occupying a like position on Bear river at the head of Portland canal, contain numerous shells of species still existing in the nearby ocean.

The estuarine deposits, and the boulder clays along the central portion of the valley, are overlaid by river sands and gravels. The older deposits were cut through as the land rose and the river deepened its channel, and now occur on benches at various elevations above the water level up to at least 300 feet.

PRINCESS ROYAL ISLAND, B.C.

(*R. G. McConnell*)

Introductory.

A few days, during the season of 1912, were spent visiting Princess Royal island, and making an examination of some quartz veins now being developed there by the Surf Inlet Gold Mines Company, Limited. The trip was made in a launch from Prince Rupert, and occupied eight days. The regular steamship channel was followed from Prince Rupert south for a hundred miles to McKay Reach, beyond which the west shore of Princess Royal island was followed to Surf inlet, a fiord-shaped channel penetrating the island from the west for a distance of about 12 miles.

On the way down, landings were made at intervals to examine the rocks exposed along the shore-lines. These consist practically of two formations, the Prince Rupert schists and the granitic rocks of the Coast Range batholith.

The Prince Rupert schists, made up largely of well crystallized quartz-mica schists passing, in places, into fine-grained gneisses, and greyish and white crystalline limestone, extend south in a wide band from Prince Rupert to the northern entrance to Grenville channel, and are well exposed along the shores of Smith, Kennedy, Gibson, White Cliff, and numerous other smaller islands fringing the mainland. Opposite the mouth of the Skeena river, the band of crystalline schists has a width of about 12 miles. It is bordered on both sides by the gneissic granodiorites of the Coast Range batholith, and, in places, is intruded by granitic dykes and stocks.

The same band of crystalline schists, gradually narrowing, is exposed on both shores of Grenville canal south to Klewnugget inlet, and on the west shore for some distance beyond. The long, straight, deep depression of Grenville channel follows closely the band of schists throughout the greater part of its course, and plainly owes its existence to their presence.

Pitt island, west of Grenville channel, is built mostly of gneissic granitic rocks, is mountainous everywhere—some of the bare grey pyramidal peaks rising to elevations of from 4,000 to 5,000 feet and, in general character, is very similar to the Coast range which borders the channel on the east.

Princess Royal island, south of Pitt island, the objective of the trip, is one of the largest islands on the coast, having a length of 60 miles, a maximum width of 26 miles, and a superficial area of about 1,000 square miles. Like Pitt island, it is monotonously rough and mountainous throughout, and contains little land suitable for agriculture. The mountains and mountain groups are not high, seldom exceeding 4,000 feet in height, but are steep, rugged, and massive and, in places, strikingly beautiful. A prominent feature of the topography is the number of narrow steep-sided and, in places, flat-bottomed valleys, which wind partially across the island, occasionally uniting and isolating groups of mountains. The valleys often contain long, narrow lakes held in by rock basins, and have evidently been moulded to their present form by ice action.

The prevailing rock on the island in the portion examined is the greyish, occasionally banded, slightly schistose granodiorite, typical of the Coast Range. Quartz-mica schists and crystalline limestones referred to the Prince Rupert formation, occur on the Surf islands opposite the mouth of Surf inlet, and in places, as inclusions in the granite along the northwestern and northern coasts, but were not identified in the interior of the island.

Mining Development.

Promising ore bodies have been known on Princess Royal island for some years, and considerable development work has been done on the groups of claims owned respectively by the Surf Inlet Gold Mines Company, Limited, and the Princess Royal Mining Company. The latter company, in the course of their operations, mined and shipped a considerable tonnage of ore, but the excessive cost of transportation to the coast, over two lakes, necessitating several handlings, rendered the venture unprofitable, and the mine is now idle. The Surf Inlet Gold Mines, Limited, is the only company doing any considerable amount of work at present.

SURF INLET GOLD MINES COMPANY, LIMITED.

Situation and Communication.

This company owns a group of nine claims, situated about 6 miles inland in a direct line from the head of Surf inlet on the west coast of Princess Royal island, and at an elevation of about 1,000 feet above sea-level. The route to the mine from the coast follows a low valley, practically a continuation of Surf Inlet valley, occupied successively by two narrow lakes known as Cougar and Deer lakes, the former trending to the northeast, and the latter to the northwest. Cougar lake is connected with Surf inlet by a short, steep, rocky channel, and with Deer lake by a swift stream a mile in length. Three and a half miles from the foot of Deer lake, a trail following the steep valley of Paradise creek, the outlet of Paradise lake, leads up to the mines.

The ordinary route of steamship travel north from Vancouver, follows the east coast of Princess Royal island, and Surf inlet on the west coast is only visited at present by the regular passenger steamers when special arrangements are made.

Rocks.

The rocks, in the vicinity of the mine, consist of moderately coarse, slightly schistose granodiorite, usually greyish in colour and showing a banded structure in places. The granitic rocks are cut by a few aplitic dykes, and more rarely by a later series of dark basic dykes.

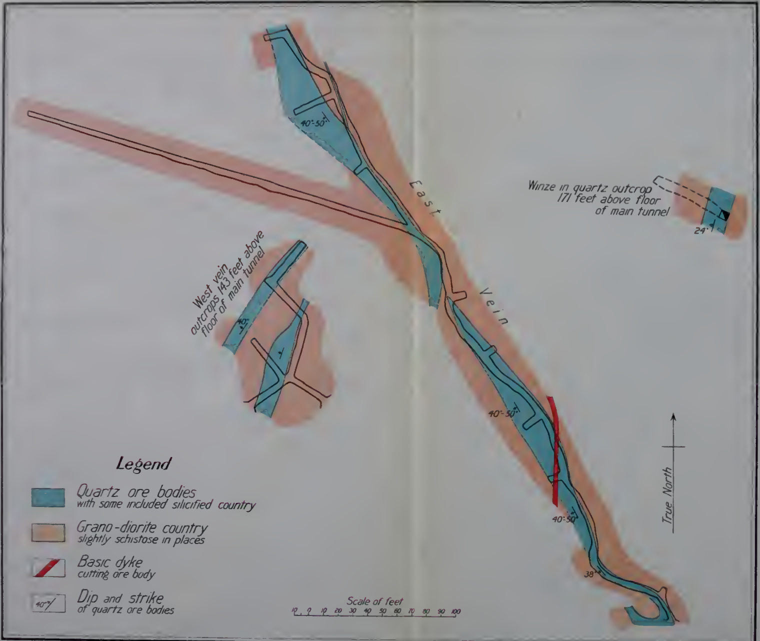
Workings.

The principal showings on the property are known as the east and west veins. The former is much the larger and has been followed practically continuously by a tunnel now over 500 feet in length. Short cross-cuts have been made at intervals to determine the width of the mineralized zone, and a long drift to the northwest intended to undercut the west vein in depth, starting at the 350-foot mark, has been carried in for a distance of over 250 feet. At the time of my visit, the vein had not been reached.

The west vein outcrops on the surface 143 feet above the main tunnel level and has been opened up by drifts and cross-cuts for a distance of 90 feet. A third important surface showing situated 260 feet north from the mouth of the tunnel, and at an elevation of 171 feet above it, has been explored by an incline shaft 50 feet in length.

Character of Deposit.

The ore bodies explored consist of quartz veins or long lenses, occupying



Geological Survey, Canada

Workings on the Property of Surf Inlet Gold Mines Co. Ltd., Princess Royal Island, British Columbia.

(From Surveys by Management, August, 1912)

To accompany Summary Report by R.G. McConnell, 1912.

strong fissure zones traversing the granodiorites. The east vein fissure zone follows a northwesterly course, and dips to the southwest at angles usually of from 30° to 50°, while the west vein has a northeasterly strike, and dips to the northwest. It is probable that the latter represents a branch from the former. The east vein, as shown in the long tunnel, has an irregular shape, and is practically made up of two long lenses separated by a short, nearly barren stretch. Further exploration may show that the lenses overlap or connect west of the tunnel. The lenses are unusually large, both of them swelling out to widths of over 18 feet measured at right angles to the direction of dip.

The quartz filling is largely, if not altogether, a replacement deposit. It is separated from the country rock along portions of its course, by definite walls, often lined with residual clay, while in others, it ceases abruptly in the unfissured granite. The replacement, as a rule, is very complete, few cores of the original rock remaining.

The west vein, so far as explored, has a width of about 6 feet. It dips to the northwest at an angle of 40°, and is underlaid by a wide band of crushed and schistose country rock in which bunches and seams of quartz have developed.

Ores and Ore Bodies.

The quartz is gold-bearing throughout and constitutes the ore of the mine. It carries considerable quantities of pyrite in places, but practically no other minerals with the exception of the gold. The pyrite occurs in grains, linear aggregates, and bunches distributed irregularly through the quartz. While it is probable that the gold, or the greater part of it at least, occurs in connexion with the pyrite, the quantity present is not a sure measure of values as high assays have been obtained from quartz nearly free from sulphides. Visible free gold has been found, but is rare.

The values in gold as shown by numerous assays made by the management, range from $2 to over $100 per ton. General samples at different points across the wide ore bodies exposed in the tunnel along the east vein give values of from $9 to $11 and in one case of $26 per ton. The general sampling so far done indicates, according to the management, average values of somewhere between $7 and $9 per ton for the whole mass of quartz in this vein. General dump samples collected by the writer and assayed in the laboratory of the Mines Branch, gave practically the same results. The values in the smaller west vein are considerably higher. A general dump sample, mostly white quartz holding a little pyrite, assayed $25 per ton in gold.

The 500-foot tunnel along the east vein and the cross-cuts from it afford a good horizontal section of the ore bodies at that level. The quartz vein at the mouth of the tunnel is very wide, but as seen in the hillside above the tunnel, it is soon separated into two portions, each about 5 feet in width, by a large central granodiorite mass. The lower vein is followed in the tunnel. It is comparatively narrow for the first 60 feet, then gradually swells, and at the 200-foot mark, has a width of 18 feet. Beyond that point, it decreases in size and appears to terminate about the 300-foot mark. The next 30 feet is comparatively barren along the course of the tunnel, although the country is strongly fissured and holds scattered bunches of quartz. At the 330-foot mark, a strong quartz vein enters the tunnel from the left, and has been followed continuously to the end of the present workings, a distance of 170 feet. The maximum width is reached at the 450-foot mark, where a cross-cut shows 22 feet of quartz with the face still in ore. At the end of the workings, the vein has diminished in size but is still strong, measuring 8 feet 6 inches at right angles to the dip.

The workings on the east vein are practically limited to one level, and afford little information in regard to the extension along the dip, either up or down, of the large quartz lenses pierced. That the second lens cut in the tunnel extends to the surface, a distance of 320 feet, is, however, rendered probable by the presence on the hillside, 260 feet north from the mouth of the tunnel and 171 feet above it, of a large quartz cropping in nearly the position the lens would occupy if projected to the surface along the average dip of the fissure zone. The surface cropping has been followed down by a winze for a distance of 50 feet, and at the bottom has a width of 18 feet. Other surface croppings of considerable size occur along the same fissure zone still farther to the north, but have not been opened up.

The workings on the fissure zone known as the west vein, have exposed a regular quartz vein 6 feet in width, along the hanging wall, and an irregular partially silicified band along the foot-wall. The country between is crushed, broken, and also silicified in places. The fissure zone has been opened up by drifts and cross-cuts for a distance of 90 feet from the surface.

Mining Conditions.

The mining locations of the Surf Inlet Company are favourably situated for cheap mining, the principal drawback being their distance from the coast. The exploratory work carried out so far, has all been done by hand labour. The results have been so encouraging that the management are now considering the installation of a power plant, and some method of cheap transportation. The distance from the coast to the mine, following the usual route, is approximately 7 miles. The first 6 miles are along a low valley mostly occupied by two lakes, the lower 26 feet and the upper 56 feet above mean high tide. It is proposed to construct a 40-foot dam across the narrow depression at the foot of the lower lake. A dam of this height would drown out the short stream connecting the two lakes, and afford easy water communication, except for a short time in winter, practically from the coast to the foot of the slope leading up to the mine. It would also ensure a continuous water supply for power purposes. A second scheme is to build a tramway along the lakes and utilize the present 26-foot fall at the outlet of Cougar lake for power purposes.

The ores, while apparently present in considerable, probably large, quantities, are only of moderate grade, and will require concentration before shipment. Tests to determine the most economical method of treatment are now being made.

PRINCESS ROYAL ISLAND GOLD MINING CO.

The claims owned by this company are situated about a mile south from those of the Surf Inlet Company, on the opposite side of the same valley.

The country rock is a medium-grained granite gneiss, usually greyish in colour, but, in places, made up of alternating light acid and dark basic bands. The gneisses strike a few degrees west of north, and dip to the west at angles usually of from 40° to 50°.

The claims are staked on a long fissure zone, running in the same general direction as the line of fracturing crossing the property of the Surf Inlet Company, and apparently a continuation of it to the south.

Two veins about 150 feet apart, occur on the property. The west vein has been explored by a tunnel for a distance of approximately 1,040 feet. A well defined quartz vein pitching to the west at angles of from 40° to 50°, outcrops at the mouth of the tunnel, and has been followed in for a distance of 240 feet. The vein varies in width from a few inches up to 4 feet. A second lens swelling out at one point to a width of 6 feet, commences at the 280-foot mark, and is exposed

along the tunnel for a distance of 120 feet. A third lens, about 30 inches in width, was reached at the 520-foot mark, and followed for 80 feet. Beyond this point only two short lenses, one 30 feet and the other 50 feet in length, were encountered.

Some stoping has been done on the first three lenses, but the shipments proved unprofitable owing to the expense of transportation to the coast.

The ores consist of quartz holding considerable pyrite in grains, bunches, and short veinlets. The values are in gold, and the average tenor is reported to be considerably higher than in the ores of the larger veins on the claims of the Surf Inlet Company. A general dump sample collected by the writer gave values of $16 per ton in gold.

The east vein has a width of from 4 to 5 feet, and has been opened up by a shaft 60 feet in depth. The quartz in this vein holds copper sulphides in addition to the iron pyrite.

Work on the property ceased some years ago, but the mine will probably be re-opened if the operations on the neighbouring claims of the Surf Inlet Company prove a success.

PICKETT GROUP.

A third group of claims, known as the Pickett group, have been staked north-east of the lower part of Bear lake, and at an elevation of 1,450 feet above it. The country rock here is similar to that at the other locations, being a moderately coarse, banded, granite gneiss. The work done consists of about 200 feet of drifting and a short winze. The drift follows a quartz vein from a few inches up to 4 feet in width, for a distance of 150 feet. The end of the tunnel is in waste, the vein having either pinched out or been lost.

The quartz contains more pyrite than usual, and, in places, the vein is partially oxidized.

TEXADA ISLAND, B.C.

(*R. G. McConnell*)

Texada island was revisited by the writer in September, 1912. The season of 1907 and part of that of 1908 was spent by him in a geological examination of the island. During the past season topographic maps of the more important sections were made by Mr. D. A. Nichols, of the topographic division of the Survey, and a general report will be completed and issued as soon as possible.

An outline sketch of the geology and mines and prospects on the island is published in the Summary Reports of the Survey for 1907 and 1908. The important iron range on the west coast of the island is still idle and at present mining activity is confined to the vicinity of Van Anda on the east coast. Two mines, the Marble Bay and Little Billy, are in active operation here, and preparations were being made to continue explorations on the Cornell.

The Marble Bay mine has now reached a depth of 1,175 feet and an excellent showing of mixed bornite and chalcopyrite ore is exposed at that level. Further explorations in the upper levels has also resulted in the discovery of large bodies of good ore in the vicinity of the ore body originally worked. In September, work on the extension of the shaft down to the thirteenth level was commenced and production was temporarily suspended. At present the thirteenth level is only reached through a winze.

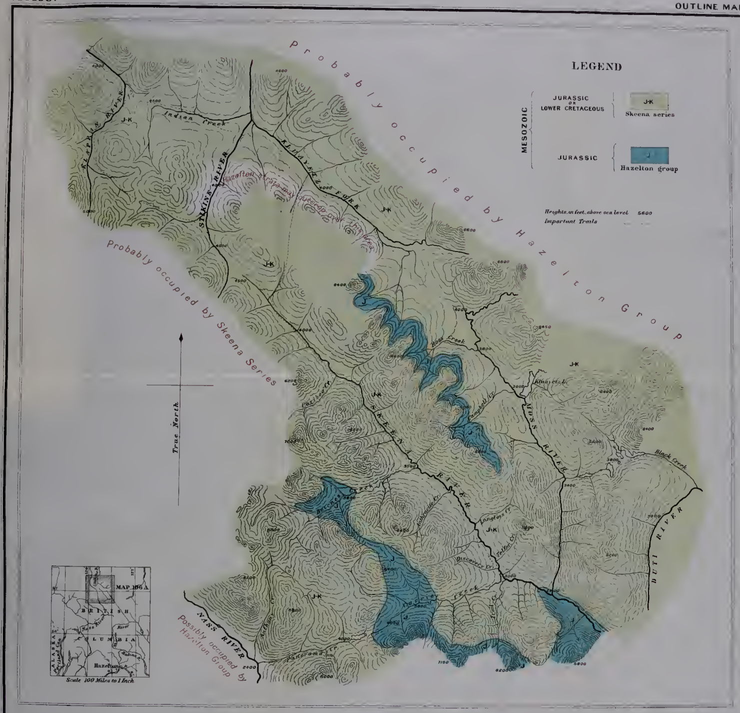
Work on the Little Billy at the time of my visit was largely concentrated on the sinking of the shaft from the second to the third levels. Considerable drifting has been done on the second level, and two moderate sized ore bodies have been found, both situated near a ragged granite-lime contact which crosses the property. These have been mostly stoped out towards the first level, and further production depends on their extension downwards.

Texada island is remarkable for the number of mineral occurrences scattered over its surface, and although it has been prospected for years, discoveries are still being reported. During the past season a small body of high grade ore was exposed in the construction of the Blubber Bay road, and located as the Charles Dickens claim. A shaft is now being sunk on it.

Canada
Department of Mines
Hon. L. Coderre Minister A. P. Low Deputy Minister
GEOLOGICAL SURVEY
R. W. Brock Director

GEOLOGY

OUTLINE MAP



C. O. Senécal, Geographer and Chief Draughtsman.

MAP 106A
(Issued 1913)

GROUNDHOG COAL FIELD, BRITISH COLUMBIA

Scale of Miles
2 0 2 4 6 8

To accompany Summary Report by G. S. Malloch, 1912

Geology, surveys, and compilation by G. S. Malloch, 1911-1912

THE GROUNDHOG COAL FIELD, B.C.

(*G. S. Malloch*)

Introduction.

The examination of the Groundhog coal field, begun in 1911, was continued in 1912, two and a half months of the field season being spent there. Of the remaining time more than two weeks were spent in making a trip to the valley of the Sustut river, and nearly two weeks more were spent in the vicinity of Hazelton. Here the coal exposures in the big slide on the Skeena were re-examined, as well as the Silver Standard, Rocher de Boule, and Harris mines. (See accompanying report on the metalliferous deposits in the vicinity of Hazelton). The writer's thanks are due to the managers of these mines for the courteous treatment he received and he must also mention his obligation to his assistant, Mr. W.Nason, who not only performed his regular duties most efficiently, but was also ready to undertake others which were necessarily assigned to him during the Sustut trip, owing to the illness of one of the members of the party.

The writer is under deep obligation to Professor Joseph Barrell of Yale University, for criticism and valuable suggestions while preparing this report.

During the season of 1912, an area of 500 square miles in the coal field was mapped on a scale $\frac{1}{192000}$ with a contour interval of 200 feet, by means of plane-table intersections developed from a triangulation made the year before. From the border of this area a telemeter and compass traverse was run to the north-eastern corner of the field and back by another route to the border of the area mapped by the plane-table. The major topographic features along the traverse were sketched and approximate locations and elevations of peaks determined by reading horizontal and vertical angles. A large number of new coal seams were discovered, many of which were carefully measured and sampled. Three additional sectio·s were measured, the first on the ridge south of Anthracite creek, a stream which rises in a large cirque 5 miles south of Beirnes creek. The second was practically a continuation downward of the main section measured last year on the crest line of the mountains west of the Skeena 5 miles from the mouth of Currier creek. The third was a continuation upward of the section on the cliff at the western end of the ridge south of the junction of the two branches of Trail creek. As a result of the comparison of these sections, the relative positions of the different coal bearing horizons in this portion of the field are pretty well established in spite of the great irregularity in the measures. No exposure of a satisfactory section was found in the northern part, which is to be regretted, since, as a result, it is impossible to do more than state the number and thickness of seams found there.

Location and Area of the Groundhog Field.

The Groundhog coal field, while somewhat irregular in outline, conforms fairly well to the following boundaries: the southern boundary runs approximately along latitude 56° 48′ for a distance of about 25 miles, extending approximately from longitude 128° .02′ to longitude 128° .41′. The general extension of the coal-bearing strata is to the north-northwest in accordance with the prevailing trend of the mountain ranges. During the past year a traverse was run to the northeast corner of the field and it was found that the distance had been exaggerated in previous reports. The extreme length of the field amounts to only 52 miles instead of 70. The northern boundary appears to be also approximately an east and west line and, from information obtained from prospectors, the western

boundary probably follows the valleys of the Nass and the main fork of the Klappan. The shape of the field, therefore, approximates a parallelogram, and its area is about 900 square miles. It is to be noted, however, that over large areas all the coal seams have been removed by erosion and that in other areas, only a very small fraction of the total number of seams has been preserved. The nearest corners of the parallelogram lie 80 miles northeast of Stewart, at the head of Portland canal, and 110 miles a little west of north from Hazelton.

History.

It is probable that coal in the Groundhog field was first discovered by prospectors who went to the Klondike in 1898 by way of Hazelton, the Skeena, the Klappan, and Telegraph creek. The first recorded discovery, however, was made by Mr. James McEvoy, in 1903, who found coal float where the main trail crosses Discovery creek, and finally located a 6-foot seam 2 miles higher up the creek. His time was limited, but he staked some claims and secured samples which showed that the coal was an anthracite with a high percentage of moisture.

In 1904, Mr. W. W. Leach visited the field with a small party, stripped seams in several localities, and staked additional claims in behalf of the Western Development Co., which had been formed to finance the claims Mr. McEvoy had staked. The total number of these claims amounted to sixteen, each one square mile in area. The field was revisited in 1908 and in 1909 when a party was sent out by the Western Development Co., in charge of Mr. J. Fred Walter, who opened new seams and a number of additional samples were secured.

In 1910, Mr. Campbell-Johnston, a mining engineer of Vancouver, staked a number of claims north and west of those belonging to the Western Development Co., and the British Columbia Anthracite Syndicate was formed. In the same year, Mr. Jackson and Mr. Amos Geodfrey visited the field and claims were staked almost surrounding those of the Western Development Co. Control of these was secured by the British Columbia Anthracite Company.

During the summer of 1911, when the writer began his examination, much additional staking was being done by prospectors, and on the properties of the Western Development Company and the British Columbia Anthracite Syndicate, large parties under Mr. McEvoy and Mr. Campbell-Johnston were at work opening up all the seams which they were able to find. Mr. Jackson had spent the previous winter in the field, and during the winter of 1911-12 a party under the direction of Mr. F. B. Chettleburg were continually at work digging out seams and erecting cabins. During the winter, the British Columbia Anthracite Company amalgamated with other companies holding large groups of claims east of the original stakings and on the east fork of the Klappan and the Kluayetz branch of the Stikine. Many other groups, however, were not included, notably a group to the west extending to the valley of the Nass and including most of the area between Currier and Beirnes creeks, and the mountain slopes north and south of them. This group was staked by Messrs. Beaton and Kobes. It is believed that another large group of claims extending up the Skeena from Beirnes creek and over the divide to the transverse valley of the Stikine have been bonded by the British Columbia Anthracite Syndicate. The total number of claims on record in June, 1912, amounted to over 460. Of these, the original sixteen were surveyed by Gore and McGregor, of Vancouver, some years ago. In 1911, Mr. A. P. Augustine, of Vancouver, surveyed forty claims for the British Columbia Anthracite Co., and in 1912 Mr. T. H. Taylor ran a meridian line north for 54 miles to serve as a base line for further surveys.

In 1912, the Amalgamated Company secured the services of Mr. George Watkin Evans and Mr. Gustav Grossmann to examine their properties, and these gentle-

men spent the entire season in the areas assigned to them. Mr. Grossmann devoted his attention to the groups of the east fork of the Klappan and the Kluayetz fork of the Skeena, while Mr. Evans covered the remaining groups, the owners of which had joined the amalgamation. The recognized standing of these men rendered it unnecessary for the writer to make any detailed examination of these areas, but portions of them were visited in working out the general structure of the field. During these visits every courtesy was shown him by Mr. Evans and Mr. Grossmann, as well as by Mr. Geodfrey, Mr. Chettleburg, and others of the company, and Mr. Evans has since sent a map of the claims he examined, part of which has been reduced to form the southeast corner of the map accompanying this report. Little was seen of Mr. Taylor, but he has also furnished a map of his line, and the writer's thanks are due to Messrs. Beaton and Kobes for an excellent sketch map of their group of claims. Unfortunately, this was not received until after the writer had completed his examination of the area. Mr. W. Fleet Robertson, Provincial Mineralogist, also visited the field in 1912 and has furnished analyses of samples which he took of certain of the seams.

General Character of the District.

TOPOGRAPHY.

The entire region examined, including the coal field and the route thereto from Hazelton, is mountainous, though the differences in elevation between the valley bottoms and the summits of the mountains vary greatly in different localities. In some cases, as in the vicinity of Hazelton, these differences exceed 7,000 feet, whereas, in other restricted areas, as for example, near the fourth cabin on the Yukon Telegraph trail, the general difference between the valley of the Skeena and the mountains is, in some cases, as low as 2,500 feet. A striking feature is that where the differences in elevation are greatest the valley bottoms are widest. With the exception of the immediate vicinity of Hazelton, the trend of the main valleys is in a general north-northwest direction, but there are many transverse valleys developed along an east-northeast direction, which are often wide and contain streams of large size. The Skeena itself partly follows transverse valleys, one near the mouth of the Babine and another for 30 miles below the mouth of Bear river. The main valleys are long extended, and in many cases contain very low divides so that on these divides streams head which flow in diametrically opposite directions. The main valleys in the neighbourhood of these low divides do not change their general character, and in passing away from the divides their widths do not increase nor is the slope of the walls decreased. As a result of the general structure, most of the drainage carried by the main valleys is derived by tributary streams entering from transverse valleys, while the divides in the main valleys are very often occupied by lakes.

In certain cases where different major valleys coalesce, one of them may have at its mouth a direction intermediate to the directions of the major and of the transverse valleys, but if followed for some distance it will usually be found to conform with the north-northwest trend. This trend may be explained by the prevailing strikes of the strata, and the irregularities near Hazelton are due to the intrusions of large masses of igneous rock which, owing to their resistance, have completely prevented the development of this natural trend of the valleys. The valleys are in general U-shaped and in many cases the rivers occupy narrow canyons, in some places 200 feet below the valley floors. In the vicinity of the fourth cabin on the Yukon Telegraph trail, although the valleys are narrower and the relief less, the Skeena valley approaches more nearly to the V-shape.

The higher mountains have most irregular crest lines accompanied by the

development of many characteristic cirques, but in the lower mountains there is a tendency towards a rounded summit, often truncated sharply by steep slopes. In general, there is a close relation between the topography and the dip and strike of the rocks.

The topography of the Groundhog coal field is somewhat complicated, but is of the same general character as that of the region south of it. Three main longit dinal valleys form the most important depressions, and there are four well marked transverse valleys. None of the latter extend for the full width of the field, but serve only to connect the central longitudinal valley with the others on either side of it. The distances between the longitudinal valleys are unequal. The valley of the Nass and main branch of the Klappan, which bounds the basin on the west, is 16 miles from the central valley occupied by the main branch of the Skeena and the Stikine, while the eastern valley is distant only about 8 miles. This is occupied by Moss creek and the Kluayetz branch of the Stikine. In the south-eastern corner of the field the valleys of the main Skeena and that of Moss creek join with an acute angle; Moss creek, after flowing in a broad flat valley for more than 10 miles, suddenly enters the narrow V-shaped lower portion and descends to the Skeena through a deep impassable rock canyon. In the extreme southeast lies the valley of the third branch of the Skeena, known as the Duti or Pebble river. About 10 miles farther north, this valley is connected with that of Moss creek by a flat valley which contains numerous lakes.

The most conspicuous transverse valley is that of Currier and Panorama creeks, the first of which flows to the Skeena, and the latter into the Nass. At the divide between the two streams is a swampy flat and a lake three-fourths of a mile long which drains to Panorama creek. The elevation of this lake is 4,150 feet and of the Skeena at the mouth of Currier creek is 3,000 feet, whereas the elevation of the Nass at the mouth of Panorama creek is only 2,400 feet. The direction of this valley is not quite at right angles to the north-northwest trend of the ranges, but is more nearly due east and west.

A second transverse valley is occupied by Beirnes and Anthony creeks, which also flow to the Skeena and Nass respectively. The mouth of Beirnes creek has an elevation of 3,500 feet and is 9 miles higher up the Skeena than that of Currier creek. The direction of this transverse valley is west-southwest for about 8 miles from the Skeena, but from this point to the Nass it gradually swings round to the southward, and the mouth of Anthony creek is not half a mile above that of Panorama creek. The elevation of the lowest part of the top of the divide is 4,500 feet.

Two other transverse valleys are occupied respectively by the main Stikine river and the east branch of Klappan river. The former heads with the main Skeena at an elevation of about 4,600 feet in a broad north-northwest valley, but the Stikine follows it for only about 4 miles. Below this, the river follows a transverse valley past the mouth of the Kluayetz and through the lofty range of mountains which borders the coal field on the northeast. The longitudinal valleys in which the Stikine and Kluayetz head, both extend northwestward beyond the transverse valley of the Stikine, being occupied by small tributaries to it and to the Klappan which, to the northwest, follows another transverse valley. The eastern valley in which the Kluayetz heads, however, turns more to the west than the one in which the Stikine rises, so that where these two main valleys cross the Klappan they are only about 4½ miles apart, and north of that river they practically unite to form one broad valley running east and west.

Both Moss creek and the Kluayetz branch of the Stikine, which head in the same main, longitudinal valley, derive most of their water from the region to the east of the field, and are already streams of large size where they break through the bordering range in comparatively narrow gaps, and enter the longitudinal

valleys. One of the gaps draining to Moss creek contains Kluayetz lake, which is 1½ miles long, and the same gap is connected with the valley of a branch of the Duti by a low divide running between high mountains. A large tributary of Beirnes creek comes in from the north about where the bend in the valleys occurs, and is said to head with a branch of the Nass and another from the Klappan.

Apart from these valleys, the country may be divided into mountains and uplands, and though no very sharp line of division can be drawn between these two classes it was noticed that the uplands, below 6,000 feet in elevation, were rounded and generally covered with a mantle of morainic material, whereas the mountains, greatly exceeding them in elevation, were crowned with sharp aretes caused by the development of cirques. In many cases these cirques drain directly to the main valleys, but in other cases the streams from them traverse the uplands for some distances in comparatively shallow valleys and then descend with a steep gradient to the main valleys. Some cirques have also been eroded into the rounded hills of the uplands, but have not usually been pushed back far enough to produce sharp ridges. As a rule they are found on the northeast side of the hills where there was a good chance for the accumulation of snow, borne by the prevailing west winds, and at the same time protection was afforded from the sun. The highest mountains occur in two groups. The first extends along the northeastern boundary of the coal field, where many peaks exceed 7,000 feet in elevation and one, the height of which was measured by vertical angles, exceeds 7,600 feet. The second group is situated west of the divide between the Skeena and Stikine, and here the height of another peak of equal elevation was measured, and a great many other peaks must exceed 7,000 feet. In both these regions large glaciers occur, but in the remainder of the field the glaciers are small and not numerous. Probably the region ranking next in elevation occurs south of Currier creek. Here one eak nearly reaches 7,150 feet and several are only a few hundred feet lower. In the area between Currier and Beirnes creeks the highest peak reaches an elevation of 6,600, but a number of peaks and aretes exceed 6,000 feet. These are found near the Skeena, while farther west the country is of the upland type. Much of it is above 5,000 feet, and, therefore, a little above the timber line which usually follows the 5,000 foot contour. In some cases, however, stunted trees extend up to 5,600 feet.

The mountains between the Skeena and Moss Creek longitudinal valleys approach most nearly to what might be called a range. Their width amounts to nearly 7 miles in places and their height reaches 6,800 feet nearly opposite the divide between Moss creek and the Kluayetz. Steeply dipping beds on the southwestern face of this range give rise to regular slopes on that side, while the northeastern is deeply cut by comparatively narrow cirques. The elevation of the range is much lower near the ends where, in places, it does not exceed 6,000 feet. Near the southern end the valley of Langlois creek extends from the Skeena two-thirds of the distance across the range, and the divide between this valley and that of a small tributary of Moss creek is only about 4,500 feet in elevation. Other passes exist through the range, but few, if any, are less than 5,000 feet high. To the north the range terminates in Klappan mountain, a long rounded mass lying between the transverse valleys occupied respectively by the Stikine and the east branch of the Klappan, and bounded on the east and west by the continuation of the Skeena and Moss Creek longitudinal valleys.

The Nass valley is bordered on the west by ranges of mountains exceeding 6,000 feet in elevation, but no very lofty peaks were noticed. Nor do any very high peaks occur for some distance west of the valley, for on a clear day the jagged and pinnacled masses of the peaks forming the boundary line between Alaska and British Columbia could be seen from elevations lower than 6,000 feet. As these peaks must be fully 70 miles away and as their actual height is not greatly

in excess of 9,000 feet, it will be seen that, on account of the earth's curvature, any mountains near the Nass and much over 6,000 feet in elevation would have obstructed the view.

None of the higher peaks to the east of the coal field were climbed, but it is reported that the country east as far as the head-waters of the various tributaries of the Peace, contains many broad valleys, separated by comparatively low mountain ranges.

CLIMATE, AGRICULTURE, AND FLORA.

The past summer, 1912, was an exceptionally dry one in the northern interior, and at Hazelton the hay crop was but a small fraction of the usual one. Frosts in July were common at Groundhog, and snow fell before the end of August. Attempts to grow potatoes proved a failure, owing to the frost, though turnips and radishes were more successful. The amount of rain is always abundant along the Telegraph trail, at least as far as Blackwater lake, but a gradual change to dryer conditions was evinced by the occurrence of jackpine and many aspen poplars at the northern boundary of the Groundhog field, while the change in the climatic conditions must be more abrupt in an east and west direction. At the junction of the Bear and Sustut rivers, jackpine were the predominating trees, while on the Telegraph trail, 40 miles east, they were almost entirely absent. Of all the trees, spruce and balsam have the widest range, extending from the valley bottoms to timber line, but may be crowded out by other trees, as, for example, by jackpine in dry climates or by hemlock on the lower slopes where the soil is sandy. After fires, aspen poplar are always the first trees to spring up, but they never attain large size. Cottonwood are confined to the gravelly or sandy banks of rivers and streams, and sometimes reach diameters of 8 feet. White birch are fairly numerous in the valleys, and a few small ones extend for some distances up the slopes. The northern extent of the red cedar ends abruptly at the divide between the Kispiox and Deep creek. Black alder occur everywhere, but especially along the Telegraph line, where they sometimes extend from the valley bottom up the slopes to within a few hundred feet of the timber line. Blueberry, huckleberry, salmon berry, mulberry, cranberry, and raspberry occur plentifully in the valleys, but are not abundant above 3,000 feet in elevation. The wild strawberry and the wild gooseberry reach th · greatest elevations, and show a decided preference for the drier regions.

FAUNA.

In addition to the grizzly and black bears, moose, caribou, goat, beaver, and whistling marmot were seen last year. Mr. Evans' party saw bighorn sheep between Moss creek and the Duti, and on the high mountains to the east of the field, and the Stikine, Indians say they are quite common.

TRANSPORTATION.

Travel from Hazelton to the Groundhog field was greatly facilitated by improvements in the trail made under the direction of Mr. Mullin. His party did a great deal of grading, particularly on the northern slope of Groundhog pass, where the old trail crossed a great deal of soft ground. Their main work consisted, however, of straightening and clearing the trail. The trail up the Skeena from the fourth cabin on the Telegraph trail was made some years ago by the Northwest Mounted Police, and extends to Fort St. John, by way of Bear lake. But the fall of trees has been so rapid that a great deal of chopping had to be done before

horses could be taken over it, and then only by means of numerous detours. It would be very desirable to build a bridge across the mouth of the Slamgeese, which enters the Skeena about 6 miles from the Telegraph trail. The Slamgeese is swift and deep for some little distance above its mouth, and it is at present impossible to ascend to the quieter reaches above because of a steep rocky cliff against which the stream swings. The ford across the main Skeena some 20 miles higher up is a good one, being little more than knee deep when crossed at the end of September, and as the river is very wide at this point it could probably be crossed with horses at any time except during the highest stages of the water.

One result of the season's work was the determination of the gradients of the transverse valleys of Panorama and Anthony creeks, along either of which it had been suggested that a railway could be built from the Nass to reach the coal field. It was found, however, that the lower courses of both these streams are deep canyons and that the average gradient from the Nass valley to the flat divide at the head of Panorama creek was $6\frac{1}{2}$ per cent, and over 7 per cent in the case of Anthony creek. As the gradient of the Nass itself in this locality must amount to nearly 1 per cent, it will be seen that a railway built up Panorama creek, even with a 3 per cent gradient, must be graded on the flanks of the mountains for over $12\frac{1}{2}$ miles in order to surmount the 1,600-foot difference of elevation, and for a $2\frac{1}{2}$ per cent grade the distance would be nearly 17 miles.

During the winter of 1912, a new pass was discovered leading from Blackwater lake up Sansixmoor creek and descending to the Skeena nearly opposite the mouth of the Duti. It was reported that this pass is below timber line, but that the descent to the Skeena is a steep one. Should another transcontinental line be built north of the Grand Trunk Pacific, it would probably pass from the Nass valley to that of the Skeena by way of the Blackwater lakes and the Slamgeese. Connexion with the basin could then be secured by a line up the Skeena, which has a gradient of only about 1 per cent.

INHABITANTS.

At one time the region about the Groundhog field was a meeting place of the Skeena and Stikine Indians. Many of the former at one time caught salmon below Blackwater lake, and other families hunted in the coal field as is abundantly proved by sharp stakes set up over groundhog holes, either to guide the Indians in stalking them or for the suspension of traps. On the other hand, the Stikine Indians have long been accustomed to make trips from Telegraph creek to Bear lake and pass up the east fork of the Klappan and the Kluayetz fork of the Stikine, down Moss creek for some distance, across to the Duti, and thence east by a pass through the mountains. These Indians still travel very generally on foot, but many of the Skeena Indians now use horses.

General Geology.

Table of Geological Formations.

Quaternary	Glacial and river deposits.
Cretaceous or Tertiary	Bulkley eruptives.
Lower Cretaceous or Jurassic?	Skeena series.
Jurassic	Hazelton group.

DESCRIPTION OF FORMATIONS.

Hazelton Group.

The rocks of the Hazelton group outcrop over almost the entire area along the route between Hazelton and the Groundhog field, except where small patches of the succeeding Skeena series remain or there have been intrusions of the Bulkley eruptives. In the Groundhog field, the Hazelton strata outcrop along anticlines on both sides of the Skeena-Stikine valley, and surround the field on all sides. The base of the formation was not seen, but not improbably it rests upon the Cache Creek series of Carboniferous age. The thickness of the formation must be many thousands of feet. Only the upper 2,300 feet were measured, and this portion overlies horizons which, at other points, overlie several thousand feet of the formation.

South of Hazelton, the group contains lava flows, but to the north these are generally, if not altogether, replaced by tuffs and tufaceous sandstones interbedded with black and more or less bituminous shales. In some cases the tuffs weather to reddish tints, but, especially in the upper part of the formation north of Hazelton, the prevailing colours are dark grey and black. The sandstones contain many rounded grains of shale similar to those with which they are interbedded. A marine horizon also occurs probably about near the base of the upper third of the formation. This horizon was recognized at many points between Hazelton and the Groundhog field and yielded poorly-preserved fossils from which the genera *Astarte* and *Inoceramus* were made out, but not the species. The amount of tufaceous material seems generally to be greater in the lower part of the formation, though near Hazelton true tuffs occur in the upper portion.

In the Groundhog field, 2,300 feet of the upper portion of this formation was measured at the base of a section extending through the overlying Skeena series. The line of division was drawn arbitrarily where the sandstones begin to carry cherty pebbles. Below this the larger grains of the sandstones are composed of grains of shale, apparently derived from the interbedded shales. Mr. Leach has noted[1] that the base of the Skeena series often consists of a conglomerate. The occurrence of a few thin beds of coal in the Skeena series, only 120 feet above the base, is a further argument for placing the dividing line in the position chosen.

The top of the Hazelton formation in the measured section consists of grey shales with larger grains of black shaly material and often divided by thin lines of bituminous matter parallel to the bedding planes; shales predominate throughout, and no great amount of tufaceous material is present except at the base of the section, which ended with a bed of tufaceous sandstone 40 feet thick. On the trip to the Sustut, some particularly massive tuffs were seen about 10 miles from the Telegraph trail, and it is not improbable that an ancient volcano was situated in that vicinity.

Plant remains are abundant throughout the formation, but in the majority of cases they consist of casts of tree trunks and branches. Sometimes, however, delicate leaf tissues have been preserved in the interbedded shales, and fossils found in 1911 go to show that the formation is of Jurassic age; these fossils are enumerated in a succeeding section of this report. In places, the black shales of this formation have been metamorphosed into schists and even the sandstones have in some cases developed enough micaceous material to give them a slightly schistose look. These areas of metamorphism are closely connected with lines of thrust faults which traverse the region.

[1] Geol. Surv., Can., Summary Report, 1910, p. 94.

Skeena Series.

The distribution of the coal-bearing, Skeena series in and adjacent to the Skeena watershed is very widespread, and the close resemblance of its characteristic conglomerates and of its fossil flora to those of the Kootenay formation of the eastern ranges of the Rockies, and to those of the Tantalus conglomerate and Labarge series at the head-waters of the Yukon river, suggest that these formations were contemporaneously formed and that many more remnants may be found in the intervening territory. Mr. Cairnes has found small areas of the Tantalus conglomerate in the Atlin Lake region, and coal is reported from near Telegraph creek, and this year it was found by Mr. Taylor on the Stikine, some 25 miles below the point where it leaves the Groundhog field. In addition to the occurrence in the Groundhog field, the Skeena series also occurs on the Sustut river from its junction with Bear river northward, and also farther south in the neighbourhood of Hazelton, where there are a number of areas underlaid by it. The most important of these areas is situated on the Telkwa river, and has been examined by Mr. Leach[1]. He also reports areas on the Copper river, and on the Bulkley, 21 miles above Hazelton. A large area extends from the mouth of the Kispiox (7 miles above Hazelton), upstream for about 10 miles on the Kispiox and about 8 miles on the Skeena. The southern part of this area is much disturbed and is cut by many igneous dykes and small batholiths, but the northern end is more regular, and the writer suggested last year the possibility that borings might reveal the presence of seams of coal of economic value. Except on the Skeena the precise boundaries of this field could not be determined, owing to the lack of exposures.

The Skeena series consists of siliceous and shaly sandstones, black, yellow, brown, and purple shales, and beds of conglomerate, composed of partially rounded pebbles of dark blue and light green cherts, the former predominating. The conglomerates also contain fragments of undecomposed volcanic ash, and it seems probable that more or less volcanic material is scattered through the entire formation. As has been stated, the base of the formation is usually determined either by a bed of conglomerate or by a siliceous sandstone containing pebbles characteristic of the conglomerates. In the vicinity of Hazelton, over a thousand feet of the formation was measured in the big slide section which was published in last year's summary. This is much the greatest thickness reported from the vicinity. Mr. Leach places the maximum thickness at between 600 and 800 feet[2]. In this section, the strata comprise soft yellow and light brown shales, with soft, crumbly, yellow sandstones and bands of black bituminous shale and five thin seams of coal. At the base, there are hard grey sandstones with the characteristic pebbles, and at the top some rather coarse, thick-bedded, grey sandstones occur, which weather to a dark brown colour.

The occurrence of the coal measures on the top of the mountains south of Blackwater lake was noted last year[3]. This exposure was examined in more detail this year, and besides very thin coal seams, fossil plants, characteristic of the Skeena series, were found. The supposition that the strata in the valley to the south belong to a still higher formation was not confirmed, but, on the contrary, it was found that the coal measures extend only for a short distance down the southern slopes and that the strata of the lower slopes of the mountain and of the valley bottom belong to the underlying Hazelton group. The formation on the mountain top shows no pebbles, though there are beds of siliceous sandstones differing in no way from those in the Skeena series. Marine fossils also occur. As the coal

[1] Geol. Surv., Can., Summary Reports for 1909 and 1910.
[2] Geol. Surv., Can., Summary Report, 1910, p. 94.
[3] Geol. Surv., Can., Summary Report, 1911, p. 78.

seams are very thin, no section was measured, but the total thickness of the formation which has escaped erosion is probably less than 500 feet.

The Skeena series, where examined on the Sustut, is much thicker than in the area just described. Fully a thousand feet of conglomerates, interbedded with brown and purplish and yellow shales, occur, and below these there is a considerable thickness of black shales and yellow sandstones, in which two seams of lignitic coal were found. The base of the formation was not seen, but undoubtedly it rests on the Hazelton group which was seen only a short distance west of the first exposures of the yellow sandstones. The pebbles of the conglomerates are only partially rounded and are scattered through the sandstones, and also occur in the shales. Much cross bedding was seen and also many fragments of volcanic rocks, as well as the characteristic chert pebbles. These pebbles occur also as irregular lenses in many of the sandstones and in the shales interbedded with them.

In the Groundhog field the measured sections indicate that west of the Skeena and north of Currier creek, the Skeena series has a total thickness of over 3,900 feet. Very probably, when deposited, it was even thicker to the north and east. The strata composing the series are heterogeneous in character, but may be divided into three general classes. The first of these is composed of highly siliceous material, either conglomerates or sandstones, consisting essentially of blue and green chert grains and pebbles cemented together by a siliceous cement into extremely hard masses. Conglomerates of this character occur at the base of the formation in many places, especially at the eastern edge of the field. A comparison of the measured sections has brought out the fact that the very siliceous beds, as well as the coal seams, occur in every section at nearly the same respective horizons, whereas a considerable amount of irregularity is manifested by the other beds. Many of these siliceous beds weather to reddish tints, but are dark grey on fracture, owing to the dark blue chert. A particularly thick and massive bed of conglomerate occurring almost at the top of the section west of the Skeena, could be traced north for over 15 miles, and caps many of the highest peaks.

The remaining sandstones of the series form the second lithological group. Though often containing pebbles similar to those in the conglomerates, these sandstones are characterized by a shaly matrix, and weather to various shades of brown and yellow. Some of these beds apparently can be correlated between the different sections, but show marked changes in thickness. In some places they seem to change abruptly to shales similar to those above and below. The shales show great variation in colour. Probably black shales are the most common, but brown and yellow shales were nearly as important, and at two distinct horizons purplish colorations were noted. It seems natural to group the shales and shaly sandstones together since it appears that they may often replace each other from section to section.

The coal seams constitute the third lithological division. A comparison of the sections shows that the various horizons of many of the seams agree as closely as might be expected, considering the probable degree of accuracy of the measurements. It seems evident, however, that certain of the seams are absent from one or more of the sections, but it is to be remembered that the seams are often so deeply buried by debris that they are easily overlooked. In one case where the writer had reason to suspect the presence of a seam, it was not until a hole 3 feet deep had been dug that the first black particles were recognized in the disintegrated fragments of shales and sandstones which had slidden down over the outcrop. Furthermore, it is believed that the tendency of heavier sandstones and shales to crush down upon the seams is responsible for some of the variations in the measured thicknesses of what, in all probability, is the same seam. Where the horizon of a coal seam in one section appears to be represented in another by beds of strong sandstone there is less chance that the seam is present, though

concealed, since, in all probability, in such cases the seam has been removed by erosion shortly after its formation. In several cases, members of the Skeena series contained fragments of shale exactly similar to that composing underlying beds. Many of these fragments were rounded, but others were more or less angular, as though the clay had crumbled off a cut bank and had been carried only a short distance by the eroding current before being redeposited. While in the field, Mr. Evans told the writer that he had found angular fragments of coal in such a conglomerate and apparently such occurrences are common in coal fields[1].

An example illustrating the regularity of one of the seams is furnished by the tunnels which were driven in 1911 by Mr. McEvoy's party on Discovery creek. In the upper tunnel the measurement of the seam in descending order was[2]: coal, 1·5 feet; bone, 0·6 foot; coal, 3·9 feet; and in the lower tunnel, 3,800 feet lower down, the measurements were almost identical, viz.: coal, 1·6 feet; bone, 0·4 foot; coal, 3·8 feet. Further study this year has led the author to believe that the same seam is exposed by the tunnel on Abraham creek, only 1,500 feet from the Skeena and 2 miles from the lower tunnel on Discovery creek. Here the measurements were: coal, 2·35 feet; bone, 0·5 foot; coal, 2·7 feet.

The following are the measured sections of the Skeena series, arranged in descending order; the figures before each division in each measured section refer to the probable depth in feet of its base referred to a common datum line which is the top of the highest bed of the first section, while the numbers succeeding refer to the thickness of each division. By this means, comparisons of the different sections can readily be made.

The first section is that on the southern edge of the Anthracite Creek cirque, and is the only one containing the highest bed. It extends downwards for 2,086 feet.

Anthracite Creek Section.

Depth. Feet.		*Thickness. Feet.*
90	Thin-bedded brown sandstone	90
227	Conglomerate in heavy beds	137
230	*Coal* (dirty)	3·5
363	Black shale with dirty *coal* seams	133
377	Coarse crumbly grey sandstone	14
395	Black shales	18
443	Brown shaly sandstones with fossil plants and pebbles	48
490	Conglomerate	47
517	Brown shaly sandstones	27
538	Conglomerate (crumbly); this thins out and is replaced by shale 300 feet to the south	21
671	Black shales with several dirty coal seams	133
726	Yellow sandstone with pebbles at base; shows crossbedding and fossil plants	55
727	*Coal* seam about	1
741	Black shale	14
764	Hard siliceous grey sandstone, weathering red	23
806	Black shales and grey shaly sandstone with some brown concretions	42
812	Conglomerate (crumbly)	6
855	Black shale and grey shaly sandstone	43
861	Greenish grey sandstone	6
924	Black shales	53
970	Greenish grey sandstone with 10 feet containing pebbles near bottom	46
1,075	Black shale and purplish shale and sandstone	105
1,076	*Coal*	1
1,214	Black shale	138
1,257	Hard siliceous sandstone	43

[1] John J. Stevenson, 'The formation of Coal beds,' Proceedings of the American Philosophical Soc., vol. II, No. 207, Oct.-Dec., 1912, pp. 444–469.

[2] Geol. Surv., Can., Summary Report, 1911, p. 85.

Depth. Feet.		Thickness. Feet.
1,505	Black shales and beds of coarse, grey, purplish sandstones	248
1,555	Grey sandstone	50
1,628	Black shale	73
1,634	Siliceous sandstone, weathering red	6
1,676	Black shale	42
1,714	Grey sandstone	38
1,743	Black shale	29
1,748	Shaly sandstone	5
1,832	Black shale, bituminous in two places	84
1,837	Sandstone, with pebbles	5
1,911	Black shale	74
1,928	Coarse grey sandstone	17
1,981	Black shale	53
2,051	Concealed (probably black shale)	70
2,068	Coarse grey sandstone, rather soft	17
2,083	Black shale	15
2,086	Dirty coal	2·5

The second section is the same as that given in the Summary Report for 1911[1], but is here given in a little more detail to bring out as far as possible the correspondence with the other sections. The tops of the two sections are nearly 2 miles apart, and, as they are measured on opposite limbs of a syncline, the corresponding divisions throughout the greater part of the sections are still farther apart.

Main Section.

Skeena Series.

Depth. Feet.		Thickness. Feet.
210	Massive bed of conglomerate	107
218	Brown shale	8
230	*Coal,* with 0·7 feet shale in centre	12
235	Brown shaly sandstone	5
245	Brown shale	10
248	*Coal*	3·2
272	Black shale	24
277	*Coal,* with 1 foot bone in centre	4·5
292	Black and brown shale	15
301	Shaly sandstone	9
309	Black shale	8
312	*Coal*	2·8
426	Brown shales and shaly sandstones, with a few streaks of *coal*	114
463	Massive bed of sandstone, with chert pebbles in lower two-thirds, shaly above	37
464	*Coal*	1
714	Black shales with a number of streaks of *coal* and ironstone concretions	250
732	Coarse sandstone soft and crumbly	8
724	*Coal* seam, dirty	2
736	Black shale	12
770	Hard siliceous sandstone, weathering red, fairly coarse in places	34
803	Black and brown shale with three thin seams of *coal*	33
804	*Coal*	1
820	Black and brown shale with ironstone concretions	16
836	Shaly sandstone	16
887	Brown sandstone with bands of calcareous shale below and chert pebbles above	51
910	Brownish shale with bands of fossilferous ironstone concretions and streaks of *coal*	23
925	Brown sandstone, fine grained above, with some pyrite crystals, coarser with chert pebbles below	15
941	Partly concealed, probably all brown shale	16
947	Siliceous sandstone weathering red	6
955	Black shale	8

[1] pp. 79 and 80.

Depth. Feet.		Thickness. Feet.
959	Shaly sandstone (streaks of *coal*)	4
960	*Coal*	1·3
981	Black shale	21
983	Shaly sandstone	2
985	Dirty *coal*	2·5
1,026	Black shale and shaly sandstone, with three streaks of *coal*.	41
1,030	*Coal*	4·5
1,071	Black shale and a little shaly sandstone	41
1,110	Beds of soft yellow sandstones with some chert pebbles and shale bands	39
1,145	Coarse sandstone with many chert pebbles below, finer above	35
1,185	Black and brown shales, with streaks of *coal*	40
1,186	*Coal*	1·3
1,208	Black shales with streak of *coal*	22
1,210	Coarse grey sandstone, with lines parallel to bedding planes	2
1,221	Black shales and streak of *coal*	11
1,222	*Coal*	1·1
1,239	Black shales	17
1,240	*Coal*	1
1,279	Black shale and shaly sandstones	39
1,299	Hard siliceous sandstones	20
1,441	Black shales and brown shaly sandstones, some streaks of *coal*	142
1,660	Black shales, separated by thin beds of brown shaly sandstones.	219
1,672	Coarse grey sandstone, weathering brown	12
1,693	Black shale	21
1,695	Dirty seam of *coal*	2
1,835	Black shales, with a few streaks of *coal* and some shaly sandstones	140
1,910	Sandstones, separated by a few bands of black shales.	75
2,065	Black shales, with a few streaks of *coal*	155
2,067	Siliceous sandstone, weathering red	2
2,417	Black and brown shales, with three seams of *coal*, apparently under 1 foot thick	350
2,417	*Coal*	0·5
2,505	Black shale and soft shaly sandstones	88
2,551	Coarse grey sandstone, weathering yellow	46
2,601	Shaly sandstones and black shales, with at least one *coal* seam not dug out	50
2,639	Coarse grey sandstones, separated by shales, weathering yellow	38
2,647	Shaly sandstones	8
2,688	Fine shaly sandstones and shales with streak of *coal* and fossil plants	41
2,689	*Coal* (roof fallen in, at least 1 foot)	1
2,800	Soft shaly sandstones and yellow shales with calcareous concretions	111
2,806	Coarser sandstone, showing banding parallel to bedding planes, weathers yellow	6
2,964	Black shales and shaly sandstones, partly concealed	158
3,025	Brown shales and shaly sandstones, with numerous concretions	61
3,221	Brown shales and shaly sandstones, sometimes with purplish tints. One bed with fossils and a streak of *coal*	196
3,435	Coarse sandstones and shales similar to the above, the shales predominating	214
3,460	Hard siliceous sandstone, weathering red	25
3,603	Black shale, with beds of concretions	143
3,609	Conglomerate	6
3,624	Black shale	15
3,624	*Coal*	0·4
3,697	Black shales and shaly sandstones, the shales predominating.	73
3,735	Massive bed of hard sandstone	38
3,821	Brown shales, with a few beds of shaly sandstone, and streaks of *coal*	86
3,822	*Coal*	0·3
3,937	Black shales and grey shaly sandstones	115
3,944	Hard grey sandstone	7

Hazelton Group.

3,974	Black shales, with a few bands of shaly sandstone	30
4,010	Alternating beds of brown sandstone (grey on fracture, and black shale)	36
4,090	Grey sandstones and black shales, the shales greatly predominating	80
4,416	Grey sandstones predominating over black shales	326
4,452	Black shales, with calcareous concretions	36
4,458	Hard grey sandstone, cross bedded with grains of black shale	6

These two sections are correlated by means of the coal seam occurring at the depth of 230 feet beneath the very heavy bed of conglomerate. The correspondence of the beds of hard siliceous sandstones at depths of 764 and 770 feet, and 1,634 and 1,612 feet will be noticed, and that of the coal seam at 724 and 727 feet. Although the correspondence of the other seams is not established yet it will be noted that in many cases the occurrence but not the precise position of seams was noted at corresponding depths. Thus, in the Anthracite Creek section, between depths of 538 and 671 feet, several seams were seen in black shales, and in the Main section, 464 feet to 714 feet, a number of streaks were noted also in black shale. Clearly, however, the beds of shaly sandstone, with scattered pebbles, do not correspond in the two sections, and indicate great irregularity in the distribution of these beds. The continuation of the Main section downwards is not given as the horizon is evidently below that of the important coal seams.

The following section on the southern slope of the ridge east of the forks of Trail creek is important, since there was little talus over the rocks and a large number of more or less dirty seams were found. The continuation of this section, measured in 1911, is also given, and together they cover 1,500 feet of strata, and probably the seams correspond with the great majority of those discovered throughout the field. The sections are correlated with the Main section by means of the seam occurring at the depth of 2,417 feet. The name Jackson Mountain section is introduced instead of the name, Trail Creek section, used last year.

Jackson Mountain Section.

Depth. *Feet.*		*Thickness.* *Feet.*
1,137	Brown shale and rather coarse crumbly sandstone	56
1,197	Blue shale, with plant remains	10
1,207	Soft yellow shale	10
1,210	*Coal*	3·3
1,243	Yellow sandstone	33
1,244	Bituminous shale	1
1,261	Black shale	17
1,266	Crumbly sandstone, with some chert pebbles	5
1,335	Yellow shale, with bed of black shale near top	69
1,341	*Coal* seam (dirty)	6
1,429	Brown flaky shale	88
1,432	Bituminous shale	3
1,457	Black shale	25
1,456	Dirty *coal*	1
1,592	Black and brown shale	134
1,612	Hard siliceous sandstone	20
1,682	Black shale	70
1,683	*Coal*	1
1,698	Black shale	16
1,709	Thin-bedded, shaly sandstone	10
1,835	Yellow and black shale	127
1,883	Rather coarse grey sandstone	47
1,924	Black shale	41
1,926	*Coal* seam (dirty)	1·8
1,988	Yellow and black shale	62
1,991	*Coal* seam (dirty)	3·1
1,994	Black shale	3
2,044	Yellow shale	50
2,048	*Coal* seam (dirty)	4·2
2,064	Yellow and black shales	16
2,088	Thin-bedded grey sandstone	24
2,089	*Coal*	1
2,102	Black and brown shale	13
2,144	Crumbly yellow and brown sandstone	42
2,145	*Coal*	1
2,150	Black shale	5

Depth. Feet.		Thickness. Feet.
2,171	Rather coarse sandstone, massive in centre, but rather shaly above and below	21
2,195	Black shale	24
2,199	*Coal* (dirty)	4
2,273	Black shale	74
2,292	Yellow sandstone, very shaly below, more massive above	19
2,314	Black shale	22
2,335	Yellow shaly sandstone	21
2,350	Black shale	15
2,351	*Coal*	1
2,366	Concealed, probably black shale	15
2,403	Heavy beds of shaly sandstone, weathers yellow	37
2,413	Black shale	10
	Coal, not dug out	
	Jackson Mountain Section—Continued. (Trail Creek Section of Summary Report 1911.)	
2,398	Massive grey sandstone, weathering yellow	21
2,413	Black shale	15
2,417	*Coal*	4·3
2,420	Black shale	3
2,438	Massive grey sandstone, weathering yellow	18
2,454	Black shale, partly concealed	16
2,455	Dirty *coal*	1·4
2,497	Black shale	42
2,501	*Coal*	3·5
2,511	Black shale	10
2,538	Grey sandstone, weathering yellow	27
2,555	Black shale, slightly arenaceous above	17
2,601	Partly concealed, probably all black shale	46
2,605	*Coal*	3·6
2,607	Black shale	2·5
2,608	*Coal*	0·9
2,623	Light yellow shaly sandstone	15
2,666	Black shale, with a few thin beds of sandstone near top	43
2,671	Coarse yellow sandstone	5
2,710	Partly concealed, probably all black shale	39
2,713	Shaly sandstone	3
2,755	Black shale rather arenaceous in places	42

The following correlations seem to hold between the Jackson Mountain, Main, and Anthracite Creek sections.

Jackson Mountain Section.	*Main Section.*	*Anthracite Section.*
1210—Coal 3·3 ft.	1222—Coal 1·1 ft.	
1266—Sandstone with pebbles, 5 ft.	1299—Hard siliceous sandstone 20 ft.	1257—Siliceous sandstone, 43 ft.
1612—Hard siliceous sandstone, 20 ft.		1634—Hard siliceous sandstone, 6 ft.
1683—Coal, 1 ft.	1695—Coal, 2 ft.	
2089—Coal, 1 ft.		2085—Coal, 2·5 ft.

A general correspondence in the broader details will further be noticed between the sections, though individual beds often do not correspond. The Jackson Mountain section is situated 8 miles southeast of the Main section.

From a comparison of the sections and of the strata throughout the basin, a subdivision of the Skeena series may be made into four groups. The depths assigned to each are taken from the sections; possibly the thicknesses vary in different parts of the field.

GROUP 1.

Depth.	
0–1300	Heavy conglomerate beds, hard siliceous sandstones, shaly sandstones, often with chert pebbles, usually yellow- or weathering yellow, brown and black shales and coal seams.

GROUP 2.

1300–2300	Essentially a succession of black, brown, and purplish shales, with subordinate beds of coarse, crumbly, grey sandstones, weathering brown, a few siliceous sandstones and shaly sandstones, with chert pebbles and numerous seams of very dirty coal.

GROUP 3.

2300–3000	A series of yellow and brown shales and grey shaly sandstones, weathering to yellow colour. These are interbedded with black shales and coal seams.

GROUP 4.

3000–3950	Coarse, crumbly sandstones and brown, black, grey, and purplish shales, also beds of hard siliceous sandstones, conglomerates, and a few coal seams.

It will be noticed that all these groups are coal bearing and that black and brown shales and shaly sandstones are common to all. The coarse, crumbly, brown-weathering grey sandstones and associated purplish shales, are characteristic of the groups 2 and 4, while shaly sandstones, weathering to yellow tints, yellowish brown shales, and well preserved plant fossils are characteristic of groups 1 and 3. These two latter groups also contain the cleanest coal seams. Group No. 4, where it occurs in the range bounding the field on the northeast, contains a much greater proportion of conglomerate beds than in other localities, and associated with the conglomerates are a large number of marine fossils, while a tendency towards a calcareous cement was noticed both in the sandstones and conglomerates. These factors suggest that the strata here were laid down along the seaward margin of a delta which was subjected to many ingressions of the sea. In group No. 2, a few marine shells occur, both in the valley of Moss creek and in that of the Skeena, but west of this valley no marine shells were found. Probably the heavy bed of conglomerate near the top of group No. 1 which extends northwest for 15 miles, represents a further advance of the sea westward.

Because of the similarity of individual beds throughout the different subdivisions of the Skeena series, and the absence of good horizon markers, it is impossible to at all sharply define the areas in which the different groups outcrop, and the task is rendered all the more difficult by the complicated geological structure which holds throughout the field. The following is, however, a general outline of the distribution of different groups.

Group No. 4.—This group outcrops along the southwestern slope of the range bounding the field on the northeast; on the top of the range between the longitudinal valleys of Moss creek and the Skeena; and on the limbs of an anticline which crosses Currier creek about 5 miles from its mouth and runs northwest across Beirnes creek a little below the main north fork. The occurrence of the Hazelton group along the axis of this anticline has already been noted, and a narrow strip of the same formation also occurs on the northwest face of the range between Moss creek and the Skeena.

Group No. 3.—This group is the most widely distributed group in the Groundhog field and occupies the greater part of the longitudinal valleys of Moss creek and the Skeena, as well as the uplands between the range east of the Nass and the anti-

cline mentioned in the preceding paragraph. In the northern part of the field, Klappan mountain and the transverse valley of the east fork of the Klappan are underlain by wide belts of strata of this group.

Group No. 2.—This group is an easily eroded formation, and although the lower beds overlie those of group No. 3 at many points in the valleys, it is probable that a considerable thickness is represented only about the areas where the succeeding group No. 1 occurs. The best exposures were seen on the northwestern slope of Jackson mountain and on the eastern slope of Table mountain, south of the valley of Langlois creek.

Group No. 1.—The lower beds of group No. 1 cap both Jackson and Table mountains and the range west of the Skeena longitudinal valley, where the greatest thickness of the formation was seen, and may occur at a few other points. Between Currier and Anthracite creeks the lower beds extend down the eastern slopes of this range, and near the mouth of Currier creek they cross the Skeena for a short distance. North of Anthracite creek the group seems to occur only near the summits of the range, but its extent westward was not determined in the area lying north of Beirnes creek, where possibly it may be present in a broad strip.

The metamorphism noted in connexion with the Hazelton group is also apparent in the rocks of the Skeena series, but more particularly in the vicinity of numerous fault lines and in regions of close folding. Not only is schistosity set up in the shales but the sandstones are often so thoroughly cleaved that the secondary planes so produced have been mistaken for bedding planes. In many cases the coal seams are so much crushed as to be reduced to powder. Quartz veins and veinlets traverse the sandstones and particularly the uncrushed coal seams, in various directions, and in some cases one or more series of fractures intersecting and offsetting each other have been filled with veinlets of quartz. Some veinlets of calcite also occur, but they are less common.

Bulkley Eruptives.

The Bulkley eruptives form huge batholiths in the vicinity of Hazelton and for some distance north of it but do not occur in the Groundhog coal field. The Rocher Déboulés, Hudson Bay mountains, Babin range, and others of the higher mountains are largely composed of these rocks, and their jagged crest line are due to the resistance which the igneous rocks offer to erosion. These rocks are obviously younger than the Skeena series, for numerous dykes and small batholiths cut through that series on both the Skeena and Kispiox rivers. Thin sections examined under the microscope show that the rocks of the main masses consist of numerous hypidiomorphic crystals of rather basic andesite and large allotriomorphic crystals of what is probably an orthoclase high in sodium. Biotite, hornblende (probably secondary), some original augite, magnetite, and interstitial quartz also occur. The rock is, therefore, a granodiorite and bears a strong resemblance to the rocks of the main batholith of the Coast range and though the eruption of this batholith is in part of Jurassic age, the eruption may have continued until middle Cretaceous time. Associated with the main batholiths and often cutting them, are dykes of granite porphyry and quartz porphyry which are apparently acidic phases of the eruption. Basic differentiations, consisting mainly of hornblende, also occur. A few lamprophyre dykes were also noticed, but these are clearly of subsequent age, perhaps Tertiary, for they show chilled faces in contact with the quartz porphyry dykes as well as with the granodiorite of the batholiths. The extensive mineralization of the Hazelton district seems to be connected with the intrusions of the quartz porphyry dykes.

A great deal of secondary calcite has been introduced in connexion with the intrusion of the Bulkley eruptives, and the surrounding rocks have been impregnated with it for some distance.

Palæontology.

The following species of fossil flora in the collection made in 1911 were determined by Mr. W. J. Wilson and Dr. F. H. Knowlton.

From the Hazelton group (lower portion):—
Baiera multinervis, Nathorst.
Podozamites lanceolatus? (L. and H.) Br.

Hazelton group (near top, on Skeena, near Hazelton):—
Gleichenia sp.?
Nilssonia sp.?

The marine horizon in the Hazelton group yielded species of *Inoceramus* and *Astarte*.

From the Skeena series Mr. Wilson and Dr. Knowlton determined:—
Cladophlebis virginiensis, Font.
Cladophlebis fishcri, Knowlton.
Nilssonia parvula (Heer) Font.
Oleandra graminæfolia, Knowlton.
Equisetum phillipsii? (Dunker) Brongn.
Zamites montana, Dawson.

From the specimens collected in 1912 the following determinations were made by Dr. Knowlton:—
Ginkgo sibirica Heer.
Nilssonia nigracollensis Wieland.
" *mediana* (Leck).
" *schaumburgensis* (Dunk.) Nath.
" sp.
Acrostichopteris pluripartita (Font.) Berry.
Thyrsopteris sp.
Cephalotaxopsis ramosa Font.
Cladophlebis virginiensis Font.
Cladophlebis falcata, Font.
Podozamites lanceolatus (L. and H.).
Zamites montana Dawson.
Oleandra graminæfolia Knowlton.

Dr. Knowlton makes the following remarks: 'One specimen is absolutely indistinguishable from *Acrostichopteris pluripartita* (Font.) Berry, as figured in Md. Geol. Surv., Lower Cretaceous, 1912, pl. xxiv, fig. 6. It has heretofore been known only from the Patuxent formation of Maryland and Virginia. Three specimens are not to be distinguished, at least from the fragments present, from *Nilssonia mediana* (Lec.), a well known Jurassic species. This is the first time, as far as I know, that it has been reported from higher beds. The other forms are the ordinary species usually associated with the Kootenay, and there can be no reasonable doubt as to the correctness of referring them all to the Kootenay.'

In 1911, only a few specimens of invertebrate fossils were found. Dr. Percy E. Raymond determined *Mactra utahensis*. In 1912, when the eastern portion of the field was visited, a larger collection was made, and Dr. T. W. Stanton has determined:—

Lima sp.
Ostria, sp. 1.
Ostria, sp. 2.
Cardium? sp.
Pleuromya? sp.

The invertebrate fauna appears to contain no species described from well-determined horizons.

Structural Geology.

North of the intrusions of the Bulkley eruptives, in the vicinity of Hazelton, the strata of the Hazelton group strike, with but few exceptions, to the northwest and the prevailing dips are to the southwest. The dips to the northeast which occur are usually at high angles, thus representing in places the steeper limbs of asymmetrical anticlines. In the great majority of cases, however, the northeastern sides of the ridges are probably composed of a succession of overthrust blocks, each accompanied by folding which is of such a nature as to point to the development of the faults from folds overturned towards the east. In one case no fewer than three such fault lines were observed between the crest of a ridge and timber line on its eastern slope, and evidences of similar faults were seen in the valleys of many streams tributary to the Skeena. In wooded country the occurrence of a strike fault is very difficult to detect unless the geological section has previously been worked out in detail, and since this was manifestly impossible in travelling from Hazelton to the Groundhog field, the author's belief in a succession of faults on the eastern slopes of the range rests partly on inference.

In the vicinity of Hazelton the strata show an upbowing about the edges of the batholiths, and as these igneous masses are usually elongated in a general east and west direction, many of the strikes at Hazelton are quite discordant with those which prevail over the greater part of the area traversed en route to the Groundhog field.

The geological structure of the Groundhog field is complex and is difficult to describe. In general the strata appear to lie in folds overturned to the northeast and whose axes strike about northwest. As a result of the structure the strata, in general, dip to the southwest, though locally the measures dip to the northeast. The main folding in many places is complicated by minor folds and crumples. The intricate structure due to the folding has been further complicated by pronounced faulting. The faults, in general, strike about north 60° west and appear to be in most cases of the nature of thrust faults by which blocks of the recumbent folds have been thrust northeastward.

There is a somewhat close correspondence between the main topographic forms exhibited in the field, and the geological structure. As already explained, four mountain ranges are present in the district and strike northwest parallel with one another and with the three longitudinal valleys that traverse the district. The most easterly of these ranges forms the northeast slope of the Moss Creek-Kluayetz longitudinal valley. The next range to the west lies between the Moss Creek-Kluayetz and the Skeena-Stikine longitudinal valley; the third range borders the Skeena-Stikine valley on the southwest; the fourth range borders the Nass longitudinal valley on the northeast and is separated from the third range by a depression.

Each of these four ranges has, in places at least, broad summit- cut by deep transverse cirques. The bounding slopes are steep, and each range presents the same broadly developed geological structure. In each case the southwestern slopes consist of strata of the two lower groups of the Skeena series, dipping to the southwest at angles of 30° to 40°. These measures appear to form the western limbs of overturned anticlines. On the summits of the ranges, strata of the lower portion of the Skeena series are exposed also, but dip and strike in various directions and, as a rule, with much lower angles of dip. These measures presumably lie close to the plane of the main anticlines expressed by the ridges, but are, in general, separated by thrust faults from the more regularly dipping strata on the southwestern slopes of the ranges.

The irregularly dipping strata of the summits are in their turn thrust northeastward over another fault block which in the case of the range lying east of the Moss Creek-Kluayetz valley, belongs to the Hazelton group which outcrops along the northeastern border of the field and marks, in a general way, the position of the main anticlinal axis of this range. In the case of the next mountain range to the west, lying between the Moss Creek-Kluayetz and the Skeena-Stikine valleys, the position of the main anticlinal axis is indicated in part by outcrops of the Hazelton group occurring along a sinuous band, striking to the northwest along the northeastern slopes of the range. The third major anticlinal expressed by the range bordering the Skeena-Stikine valley on the west, is also indicated by an irregular band-like area of the Hazelton group striking to the northwest along the southwestern summit of this range. The fourth major anticlinal axis, developed in the lower strata of the Skeena series, follows the southwestern side of the summits of the range bordering the Nass valley on its northeastern side.

The northeastern slope of the anticlinal range bordering the field on the east was not visited but presumably exhibits the same general structures believed to be present in the three parallel ranges lying to the west within the limits of the coal field. In the case of these three main ridges on their northeastern slopes below the major anticlinal axes, the strata belonging to various divisions of the Skeena series dip in general to the southwest, and apparently form the eastern overturned limb of the major anticlines; but these measures are also traversed by thrust faults and furthermore in places at least are bent in major or minor synclines.

The four mountain ranges are thus believed to represent, in a general way, overturned major anticlinal folds deformed by thrust faults and minor crumples and folds. The three main, longitudinal valleys and the parallel depressed area lying between the Skeena-Stikine and the Nass valleys, are believed to mark, in an analogous fashion, the positions of the major synclines along which, in general, the strata are less steeply inclined than on the limbs of the folds. These synclinal portions are doubtless bounded by thrust faults and are deformed by minor crumples and folds, but the geological structures are not clearly exposed in these over-lying areas where drift and forest growth hide the bed-rock.

The above description gives, in a generalized fashion, an outline of the major structural features of the field. But, owing to the presence of minor crumples and folds and perhaps more especially because of the presence of the numerous thrust faults which do not strike parallel with the main axes of folding but cut across the axial lines at an acute angle, there are many exceptional features that apparently do not correspond with the general plan. For instance, the range lying west of the Skeena-Stikine divide is capped by strata of the highest group (No. 1) of the Skeena series forming an area 4 to 6 miles wide, in which the strata generally exhibit a flat synclinal structure, but, in common with the rest of the field, are crossed by faults.

The thrust faults which so complicate the general structure, strike about north 60° west and, therefore, cross the ranges which strike northwest at an acute angle.

Apparently these faults as seen on the bounding slopes of the mountain ranges extend across the ranges, and in some places can also be traced across the main longitudinal valleys. For example, two fault lines can be distinctly seen just above timber line on Alec mountain, northwest of the mouth of Beirnes creek. One fault is exposed in the strata on the creek banks about 2¼ miles from its mouth and two faults cross the Skeena, one just above the mouth of Langlois creek and the other at the apex of a bend to the west, about 2,000 feet farther down. A sharp fold or fault occurs on Telfer creek in such a position that it is nearly in line with these other points.

The emergence of fault lines on the western slopes of the ridges was not definitely recognized except at a few points, but at some points where the continuation of fault lines might be expected, the topography shows irregularities as though the steeply dipping beds had been displaced. For example, the contours of the range east of the Skeena swing more to the north just below the mouth of Cariboo creek and then back again farther upstream. A fault to which this offsetting might be ascribed, was seen near timber line on the mountain northwest of Cariboo creek and could be traced for a long distance on the crest of the range east of the Skeena. The irregularities resulting from the fault blocks on the northeastern sides of the ranges are much more pronounced, for here the strata affected are much flatter and hence there is much more lateral displacement of the hard beds. The range west of Moss creek from the pass at the head of Langlois creek, north to the Kluayetz fork, exhibits two well defined re-entrants and the faults thus expressed by the topography were seen in the field. In the range west of the Skeena, at least one well-marked re-entrant occurs, at the apex of which is the transverse valley of Beirnes creek, and in this case, again, a fault was seen.

In nearly all cases the faults are marked by steeply dipping beds striking approximately parallel to, but in reality a little to the north, of the direction in which the faults extend. As has been stated, this direction is about north 60° west. The steep inclination of the beds seems to be due to the drag effect of the faulting and the beds near the fault lines exhibit the pronounced metamorphism which has been described. In many cases where coal seams occur in these steeply inclined strata, the coal is crushed to powder and intimately mixed with fragments of shale as though there had been differential movement between the beds on either side.

The structural features which have so far been described pertain to the whole Groundhog field except near its southern and northern ends.

The structure of the portion of the field south from a line joining the mouths of Anthracite and Anthony creeks, exhibits important modifications. Except in the vicinity of the fault lines, the strata in the mountains south of the Currier Creek transverse valley dip to the north at angles of from 20 to 30 degrees. This northerly dip is reduced to about 10 to 20 degrees in the transverse valley and a short distance north of it the general dip is changed to the south, but at low angles. These southerly dips extend as far as Anthracite creek with only a few exceptions and, even in the rest of the basin, it appears that the flattest strata on the axes of the synclines exhibit, as a rule, southerly dips.

The fact that the strata in the greater part of the field remain at about the same horizons is explained by the overthrust of the oblique faults. South of Anthracite creek, however, where the southerly dips are pronounced, the lower beds of the highest group of the Skeena series make their appearance both in the Skeena valley and on Table mountain east of it. The fact that still higher beds are not seen there is due to the faults, three of which at least were observed on the Skeena, each with upthrow to the south-southwest.

Another modification of the geological structure at the southern end of the field is the fact that the fault lines which were nearly straight, striking north

60° west in the central portion of the field, are bent to a more nearly east and west direction in the southern portion. One of these faults could be traced on the northern faces of the mountains south of Currier creek for nearly 7 miles and it swings around until its strike is north 78° west. As the overthrust block is composed of strata far down in the Hazelton group, this fault line forms the boundary of the field for this distance.

Another feature of the southern end of the field is the occurrence of a large area of easterly dipping strata on the crest and eastern slopes of the mountain northwest of the mouth of Currier creek. It also seems likely that in this area, the faults which occur have small throws.

The writer's time in the northern border of the field was limited, but apparently the structure there is analogous to that of the southern end. The rocks in the range running west from the east fork of the Klappan, dip at about 30 degrees to the south and on Klappan mountain an inclination to the north was observed, features which correspond with the dips south and north of the Currier Creek transverse valley. Two well defined fault lines were also seen, and apparently these also bent rather more to a westerly direction on the bordering range.

Geological History.

The record of geological history is not an extensive one, since the oldest known formation is of Jurassic age. Probably this was laid down in a shallow sea bordered by land upon which volcanoes were active. Since the basal tuffs are red in colour it is probable that in early Jurassic or possibly Triassic time the climate was arid. This was probably succeeded by more humid conditions, for not only are the higher beds of dark sombre hues, but the number of tree trunks encased in the formation show that there must have been an abundant vegetable growth on the land. It is probable that the volcanic activity was continued, for certain of the tuffs contain unaltered feldspar phenocrysts. These would probably have been decomposed by humic acid had they been derived from the land. The shallowness of the sea seems to be demonstrated by the numerous pieces of black shale occurring in the tufaceous sandstones, and also by the presence of lamellibranchs of the genera *Inoceramus* and *Astarte*.

With the beginning of the Kootenay period, the elevation of the Coast range must have progressed far enough to expose the Cache Creek series to erosion, for it seems certain that the dark blue and green chert pebbles have been derived from this formation. The Skeena formation in the Groundhog field seems to have been accumulated in the form of a delta, across which a large river swung and over the eastern half of which the sea transgressed at intervals. This interpretation is supported by the discovery of marine shells only on the east side of the field, the correlation in the different sections of the well assorted siliceous sandstones, and the irregularity of the poorly assorted shaly sandstones with pebbles which were probably deposited by the river. At one point on the mountain southeast of Kluayetz lake, a well assorted conglomerate thinned rapidly to the west, while in another case noted in the Anthracite Creek section, a poorly assorted crumbly conglomerate, 21 feet in thickness, thinned out and was entirely replaced by shale 300 feet to the south. The imperfect rounding of the pebbles would go to show that the delta was built by a comparatively short river and the fragments of volcanic rock occurring with the chert pebbles would strengthen this supposition. Probably the river was subject to heavy floods, for the coal seams, undoubtedly formed by vegetable accumulations in extensive swamps bordering the river channels, contain a great many shaly partings and lamellæ.

The small patch of the Skeena series found on the mountain south of Blackwater lake was probably formed in the embayment at one side of this delta. Marine fossils, but no conglomerate, were found in it. The thin streaks of dirty coal found in it may represent only residual soils very high in humus. The burial of such soil was probably accomplished by ingressions of the sea.

The area of the Skeena series seen on the Sustut suggests that there had been a rapid uplift of the land before the close of the period. While the shales and sandstones with which the coal seams occur are very similar to group No. 3 of the Skeena series in the Groundhog field, the succeeding conglomerates find no analogy there, for their great thickness, the small degree of rounding of the pebbles, and their intermixture with sands and even clayey material would suggest rapid decomposition of material carried by torrential streams.

The area of the Skeena series on the Skeena and Kispiox rivers, a short distance above Hazelton, does not seem to have been subject to ingression by the sea, but points rather to deposition on river flood-plains. In this case the coal seams may have been accumulated in swamps formed by the silting up of oxbow lakes. The sediments are of a predominating yellow colour and show cross bedding in some of the coarser sandstones. These sandstones are crumbly from the intermixture of much shaly material as though there had been a very imperfect assortment.

As has been pointed out, the intrusion of the Bulkley batholiths in the vicinity of Hazelton probably occurred in the middle or late Cretaceous, clearly before the folding of the strata to the north, for near the batholiths the strata show no trace of such disturbance, and the general elongation of the batholiths is transverse to the axis of the folds.

The geological period in which the folding took place cannot be definitely determined. The writer considers that it probably occurred in late Tertiary or even in the Pleistocene. In 1910,[1] Mr. Leach visited an area on the Bulkley of sediments of Tertiary and probably of Oligocene age which were unconformable on the Hazelton group, but which had been very highly flexed and faulted.

The folding in the Groundhog field seems to have been very complex. The normal structural features occurring in the middle of the field would seem to imply the development of broad folds traversing the field in general northwest directions and approximately parallel to the present ranges. Four of these anticlines probably corresponded with the four prominent longitudinal ridges. The valleys of the Nass, the Skeena, and Moss creek correspond with synclines, while the main tributaries of Beirnes and Currier creeks probably correspond with a fourth. The last step in the development of the structure was the development of the belts of steeply inclined strata, indicative of faulting which may have been caused by a compressive force acting from the south-southwest. Such pressure would probably accentuate the southwestern dips on the southwestern limbs of the anticlines and overturn the beds forming the northeastern limbs. The fact that the axes of the folds were not quite at right angles to the supposed new line of pressure is a probable cause explaining why the belts of disturbance have sometimes a width of half a mile and why secondary cleavage is often developed along these belts. It was also found that where coal seams outcrop in the disturbed belts that they are often crushed to powder and intimately mixed with fragments of the bordering shales as though there had been differential movement of the beds on either side. Such movement may have been necessary in order to compensate the varying resistances in the different beds which would be fractured at different points, owing to their oblique position in regard to the fault planes.

Probably, also, the irregular extent of the different component strata in the formation and their varying powers in transmitting thrust, played an important

[1] Geol. Surv., Can., Summary Report, 1910, p. 95.

part in the development of anomalous types of structure. For example, the thick bed of conglomerate occurring on the mountains west of the Skeena-Stikine valley, seems to have been strong enough to preserve the original folding in the strata underlaid by it. This would account for the fact that the only extensive areas with dips to the northeast occur west of the Skeena, but such a relation is merely suppositious, for since the highest beds in the upper group of the Skeena series occur only west of the Skeena, therefore the original limitation of this particularly strong bed of conglomerate to this locality cannot be proved. It was noticed, however, that the thick conglomerates in the lowest group of the Skeena series are practically limited in the southern part to the field, to the mountains east of Moss creek, while farther north they occur as far west as the Stikine longitudinal valley and on Klappan mountain. It, therefore, seems that they must have extended in a west-northwest direction or approximately parallel to the lines of disturbance, and it is also likely that the thick conglomerates in the uppermost group of the Skeena series, extended in a parallel direction but at some distance farther to the west.

As a cause for the exceptional northerly and southerly dips at the south end of the field, the writer would suggest that the gradual consolidation of the vegetable matter in the coal seams would produce a sagging of the strata and that under the influence of the subsequent pressure, this sagging would be accentuated. A study of the sections will show that the total thickness of coal in the field amounts to about 80 feet. It has been estimated that from 8 to 20 feet of peat are required to produce one foot of coal[1]. If the latter figure is a correct estimate, the sagging of the beds from this cause in the Groundhog field might amount to 1,600 feet, but if a sagging of even only 8 feet had taken place, an initial dip of over 1 degree might have been produced in a strip of country 5 miles wide. This is the present distance from the bounding fault at the southern end of the basin, to the belt where the northerly dips flatten out. It is assumed in this explanation, that the original boundary of the delta coincided closely with the present boundaries of the Skeena series, an assumption which cannot be definitely proved. But the occurrence of marine fossils and absence of conglomerates in the small area of the Skeena series occurring on the mountains south of Blackwater lake, a position 25 miles almost directly south of the mouth of Currier creek, shows that the delta did not extend for this distance to the south. Still further compression of the coal seams may have resulted from the pressure which produced the faults, and this may account for the bending of the fault lines.

With regard to the change of the coal to an anthracite and the development in it of many quartz and a few calcite veinlets, it will not be out of place to mention a paper read by Mr. D. B. Dowling before the Canadian Mining Institute in 1909[2]. He calls attention to the fact that in experiments on peat subjected to pressure and heat, no gas is given off in raising the carbon percentage, and water is the only substance extracted. He then calculates the percentage composition of a typical peat at various stages after the removal of successive quantities of water and finds that the calculated compositions approximate closely the composition of typical coals, but in all cases the percentage of oxygen is slightly higher in the calculated results than in the actual coals. He, therefore, concludes that some CO_2 is also removed, probably about one part to eight of water. In the case of the Groundhog field, pressure was undoubtedly a factor in the production of the structure revealed, and the abstraction of water from the coal and the water's power of dissolving and reprecipitating quartz when under high but variable pressures may account for the quartz veins in the coal seams. The fact that the proportion of quartz veinlets

[1] See Economic Geology, vol. II, Jan-Feb., 1907, pp. 44-45.
[2] Journ. Can. Min. Inst., vol. XII, 1909, pp. 254-272.

in the seams is much greater than in the sandstones and shales may be explained as due to the coal being continually compressed and thus offering particularly favourable channels for the circulation of water. The presence of the subordinate amount of calcite may also be explained on the assumption that a little CO_2 was abstracted from the coal, as Mr. Dowling has suggested.

Another reason for believing that the folding in the region took place in late Tertiary or Pleistocene time can be deduced from a study of the topography. The relief, as has been shown, is structural, i.e., the ranges correspond with anticlines and the valleys with synclines. Had the folding been of Cretaceous or early Tertiary age, it is not improbable that these conditions would have been reversed, or at least a better correspondence between the elevation and the relative resistance of the different formations would have been produced. It is true that there is a partial correspondence of this nature since the higher elevations are almost invariably capped by conglomerate beds, but yet many rounded hills are still capped by the soft shales of group No. 2 at elevations of from 1,000 to 2,000 feet above the valleys.

The flat tops of the hills between 5,000 and 6,000 feet in elevation are suggestive of a two cycle period of erosion. In the first of the cycles the valleys were probably cut only to the tops of these uplands. Glacial erosion was undoubtedly a most important factor in the development of the second cycle in which the present U-shaped valleys were produced. The extensive development of cirques is also to be noted.

Economic Geology.

The main economic interest in the geology of the district examined, is centered in the coal seams occurring in the Groundhog field.

The following seams were reported by Messrs. Beaton and Kobes on their sketch map to which reference has already been made. On the Nass river they saw float coal in two places; on Panorama creek a 3 foot and a 6 foot seam, and similar seams in the mountain southeast of the mouth of Panorama creek. On the mountain between the south branch of Panorama creek and the head-waters of Beaton creek (a tributary of Sowmalda creek) they report a 20 foot and a 12 foot seam, and a 6 foot seam on the head-waters of Beaton creek. Near the mouth of Anthony creek they found a 3 foot seam, near the head of Beirnes creek a 12 foot and 16 foot seam, and farther down, near the mouth of the second tributary from the north, a 6 foot seam. On the head-waters of Meadow creek, a large tributary of Currier creek from the north, they discovered two 4 foot seams and a 6 foot seam. Besides these seams, whose thicknesses they determined, they found coal wash in a great many other places. The writer also saw much evidence of coal but actually measured only three seams in this area. The first of these was on the first large tributary of Panorama creek from the south. It outcrops on the northern bank about 200 yards south of the mouth of the stream, and 70 feet above it. The thickness of this seam is 4½ feet and it strikes 118° and dips 42° to the northeast. One 8-inch seam occurs at the stream level below this. The rocks in this locality are much crumpled. On the main south fork of Anthony creek, measurements were made of the following seam in descending order:—

Coal	2·95 feet
Bone	1·00 feet
Coal	2·25 feet
Bone	0·75 foot
Coal	0·9 foot
Total	7·85 feet
Total coal	6·1 feet

A sample was taken omitting the bone and quartz stringers, and an analysis by Mr. F. G. Wait gave the following result:—

Moisture	4·09
Volatile comb.	8·48
Fixed carbon	46·29
Ash	41·14

The high percentage of ash is due to fine lamellæ of bone occurring in the coal. The seam strikes 76° and dips to the south at 17°. It is probable that this seam belongs to the group No. 2 and that nearly all the other seams in this portion of the field belong to group No. 3, but the want of continuous exposures made it impossible to determine the exact horizons. A picked sample from the 12 foot seam on the mountain between the south branch of Panorama creek and the head of Beaton creek, given to the writer, was analysed last year[1], with the following results:—

Moisture	3·83
Vol. comb.	8·80
Fixed carbon	82·98
Ash	4·39

From a comparison with the other seams the writer doubts whether a sample across the entire seam would yield nearly so low a percentage of ash.

On the ridge east of the junction of the three forks of Trail creek, the seam occurring at the depth of 1,210 feet in the Jackson Mountain section was sampled and the results of Mr. Wait's analysis are as follows:—

Moisture	10·16
Vol. comb.	23·73
Fixed carbon	45·79
Ash	20·32

This seam is 3·3 feet in thickness and has been weathered. Near the summit of the ridges south of Jackson mountain and west of the summit of the Groundhog pass, a seam measuring 6·2 feet was sampled and the following are the results of the analysis, also by Mr. Wait:—

Moisture	10·52
Vol. comb.	22·15
Fixed carbon	40·81
Ash	26·52

This seam strikes 127 degrees and dips 40 degrees to the south and is very near the fault line by which the rocks of the Hazelton group have been overthrust so as to form the southern boundary of the field. This seam probably belongs to No. 2 group. As has been stated, no close examination was made of the seams belonging to the British Columbia Anthracite Company holdings, but some facts were gathered in their property both on Currier creek and on the Skeena. Currier creek was examined from the mouth of Canyon creek, a small creek entering it from the south about 4 miles up. Near this creek the strike is 124 degrees and dip 20 degrees to northeast. A coal seam 2 feet in thickness occurs a short distance above the mouth of Canyon creek, and on Canyon creek a dirty seam designated as 'C1' is exposed on the south bank. Between this point and a point a mile above the Skeena, the abrupt changes in dip and strike of the strata indicate four faults besides numerous crumples. The 'C1' seam was seen again farther down, also two other seams, one with 3 feet of fairly clean coal and another with 2 feet of coal overlying 2 feet of bone. All these seams probably belong to group No. 2. The two seams mentioned last are on property of the Western Developmen Company. Other seams on the property of the British Columbia Anthracite Company

[1]Summary Report, 1911, p. 89.

were found on the Skeena below the mouth of Anthracite creek. In lot 2190, a seam 4 feet 7 inches thick, was measured, and it is repeated twice farther down owing to faults as the dips are to the south at low angles. Abrupt changes in strikes also occur. The occurrence of a 3·4-foot seam on the north slope of Jackson mountain and 2·65 miles south of the mouth of Currier creek was mentioned in last year's Summary (p. 87). It is just within lot 985.

The most important seams on the property of the Western Development Company, if not the most important seams in the entire field, outcrop on Discovery creek, the lowest $2\frac{1}{4}$ miles from its mouth and the other 3,800 feet higher up. The measurements of these seams have already been given. In the upper tunnel they are: coal, 1.5 feet; bone, 0·6 foot; coal, 3·9 feet; And in the lower: coal, 1·6 feet; bone, 0·4 foot; coal, 3·8 feet. At the higher tunnel the strike is 151° and the dip 19° to the northeast, and at the lower the strike is approximately parallel but the dip is only about 5° in the same direction. The following analyses of the coal from the two tunnels are taken from the Summary Report for 1911, and the result of an analysis by Mr. Wait of a sample taken by the writer this year is added.

Locality.	Sampler.	Moist.	Vol. comb.	Fixed carbon.	Ash.
Upper tunnel......	McEvoy.....	2·62	6·96	84·49	5·93
Lower tunnel.........	McEvoy.....	1·17	6·54	83·37	8·92
Lower tunnel.........	Malloch......	2·88	7·64	78·84	10·64

In both cases not only the band of bone but all quartz stringers and nigger heads were rejected in taking the sample. The amount of quartz and nigger heads exposed at the face of the lower tunnel was measured. The tunnel face measures 5·7 feet horizontally and 5·5 feet vertically. It is crossed diagonally by a quartz stringer with an average width of 1 inch and three parallel stringers, 2 with widths of $\frac{1}{4}$ inch and one with width of $\frac{1}{8}$ inch. Two stringers occur in bedding planes near bottom, each with a width of $\frac{1}{4}$ inch and two stringers each 2 feet long are present in the lower left hand corner cutting bedding planes at a low angle, these also average $\frac{1}{4}$ inch in width. The three-tenths of a foot streak of bone has already been mentioned. Nigger heads of the following dimensions occur, one, 3 inches by 2 inches, one 4 inches by $\frac{3}{4}$ inch, and one 2·6 feet by 2 inches extending beyond the face. Considering the quartz and nigger heads $1\frac{3}{4}$ times as heavy as the coal, they would amount to 20 per cent of the total tonnage from the seam, and omitting the band of bone three-tenths of an inch in thickness which could easily be separated in mining the coal, there would remain about 10 per cent of quartz and nigger heads. If, as experience in some other regions seems to indicate, the nigger heads are chiefly surface occurrences, then, under mining conditions, there would remain about 7 per cent of quartz occurring in veins provided the exposure of the seam in the tunnel face furnishes a fair average of the amount of quartz present.

What is almost certainly the same seam, outcrops on Abraham creek, a small tributary which enters Currier creek very near the Skeena. The measurements of this seam are as follows: coal, 2·35 feet; bone, 0·5 foot; coal, 2·7 feet. The strike is 54 degrees and the dip $16\frac{1}{2}$ degrees to the north. Two analyses of samples from this seam were given in last year's Summary and a third is now available. It was made from a sample taken by Mr. W. Fleet Robertson. These analyses are as follows:—

Sampler.	Moisture.	Vol. comb.	Fixed carbon	Ash.
McEvoy	1·17	6·05	76·20	16·58
Malloch	1·04	8·39	67·89	22·68
Robertson	2·50	8·10	62·30	27·10

This seam is probably the same as the 4·5-foot seam at a depth of 1,030 feet in the Main section.

The big seam on Trail creek into which the 50 foot tunnel was driven, was also sampled by Mr. Robertson. This seam has a total thickness of 7·6 feet but is composed very largely of bone. The analyses are as follows and in all probability different widths were sampled in each case:—

Sampler.	Moisture.	Vol. comb.	Fixed carbon	Ash.
McEvoy	1·39	5·75	63·02	29·84
Malloch	1·36	7·17	49·04	42·41
Robertson	2·5	6·1	42·6	48·8

The seam strikes 133 degrees and dips 17 degrees to the northeast. What is probably the same seam was discovered and dug out on the high west bank of the Skeena about 1¼ miles above the mouth of Currier creek. The following measurements were made, and a sample taken across the seam, but omitting the bone and shale nigger heads and quartz, was analysed by Mr. Wait. The following are the results:—

Bone, with some clean coal	1 foot 3 inches
Coal (rather dirty)	2 feet 1 inch
Shale	7 inches
Coal, with many quartz stringers	2 feet 0 inches
Bone	6 inches
Coal	1 foot 1 inch
Bone with some coal	6 inches
Coal	2 feet 1 inch
Bone and some coal	5 inches
Total	10 feet 6 inches
Total coal sampled	7 feet 3 inches

Moisture	3·84
Vol. comb.	7·85
Fixed carbon	51·17
Ash	37·14

In taking this sample, as in all the others during 1912, no quartz or niggerheads were included.

The horizon of this seam is in black shale above a succession of yellow shaly sandstones and the horizon is probably the same as the 4 foot seam at depth of 2,199 feet in the Jackson Mountain section.

The outcrop of a seam 4·4 feet in width on Davis creek, near the mouth, was reported last year. The strike is about 8 degrees and dip about 21 degrees to the south. The analyses were:—

Sampler.	Moisture.	Vol. comb.	Fixed carbon	Ash.
McEvoy	1·40	6·06	70·68	21·86
Malloch	1·57	7·55	65·52	25·36

What is probably the same seam outcrops on the Skeena at some distance above Langlois creek and probably it corresponds with the 1-foot seam at depth of 2,351 in the Jackson Mountain section. Only a short distance above the mouth of Langlois creek, two lower seams were seen. The lower of these is on the east side and was apparently quite thick, but no accurate measurements of it could be made owing to a slide of sandstone blocks from above. A picked specimen containing a little quartz yielded the following analyses:—

Moisture	3·24
Vol. comb.	7·67
Fixed carbon	68·92
Ash	20·17

The upper seam on the west side was measured with the following results; it was not sampled as it was evidently very dirty.

Coal	0·6 foot
Shale	0·9 foot
Coal	0·6 foot
Bone	0·1 foot
Coal	0·8 foot
Bone	0·1 foot
Coal	0·3 foot
Total	3·4 feet
Total coal	2·3 feet

The strike is 152 degrees and dip about 40 degrees to the northeast.

As in the case of the Western Development Company, no work was done on the property of the British Columbia Anthracite Syndicate in 1912. The writer hoped to be able to sample the Ross seam which had not been fully dug out when he left the field in 1911. It was found, however, that the tunnel, like the others on Beirnes creek, had caved in. No satisfactory coal was seen on the dump. The analyses of the samples taken from the Pelletier and Scott seams are repeated.

	Moist.	Vol. comb.	Fixed carbon	Ash.
Pelletier seam	1·35	7·69	61·90	29·06
Scott seam	1·08	7·06	64·97	26·89

Samples of these seams taken by Mr. McEvoy showed even higher percentages of ash. The Pelletier seam sample represents 5·2 feet of coal, but the beds are disturbed and the dip is nearly vertical. The sample of the Scott seam represents 5·3 feet, omitting 0·2 foot of bone, and there were 2 feet of bone and dirty coal above. It is not impossible that the Scott seam represents the big seam on Trail Creek into which the 50-foot tunnel was driven.

No satisfactory roof was found for the Benoit seam, so that no reliable meas-

urements or samples are available, but three analyses of picked specimens from it yielded between 6 and 8 per cent ash. These seams, with the Choquette and Garneau, all occur in a shallow syncline which steepens suddenly near the outcrop of the Pelletier seam. The strike throughout the greater part is about 139 degrees and the dip as high as 26 degrees to the northeast. About a mile and a half up Beirnes creek from the Pelletier seam two seams occur. The upper showed 6 feet dirty coal, 8½ feet shale, 3 feet coal; the lower, coal, 2·4 feet, bone, 2·6 feet; coal, 5·8 feet. The strata are disturbed here and the seams may be locally thickened. It was found impossible to determine the horizons of these seams.

The lower two seams on Anthracite creek were described last year. The first showed bone and dirty coal, 4 feet, cleaner coal, 2·4 feet. The seam is much crumpled and possibly it corresponds with the seam in the lower tunnel on Davis creek. The second showed 4·2 feet of coal and would have been sampled this year, but the tunnel had caved. No. 3 was measured and sampled with the following results:—

Coal	28 inches
Bone and dirty coal	6 inches
Coal	19½ inches

This seam strikes 92 degrees and dips 21 degrees to the south. Mr. Wait's analysis of a sample, omitting the bone and dirty coal, is:—

Moisture	6 09
Vol. comb.	13·70
Fixed carbon	65·52
Ash	14·69

A picked sample from it analysed last year for Mr. Campbell Johnston gave:—

Moist. and vol. comb.	6·98
Fixed carbon	86·74
Ash	6·15

A number of seams occur on the last branch of the Klappan, and were prospected by Mr. Grossmann's party. A much crushed seam in the disturbed belt occurs and outcrops both on Conglomerate creek and on the creek immediately east of the Indian graves. Other seams are reported on Slate creek and near the head of Indian creek. A large seam on this fork of the Klappan, about 4 miles above the graves, had been trenched by Mr. Grossmann's party and was measured and sampled with the following results:—

Coal	14 inches
Bone and dirty coal	9½ inches
Coal	32 inches
Bone	3 inches
Coal	22 inches
Bone	15 inches
Coal	29½ inches
Total	10 feet 5 inches

Total coal sampled, 6 feet 1½ inches.

More bone and coal occurred both above and below, but none of it was clean. Mr. Wait's analysis is as follows:—

Moisture	4·48
Vol. comb.	9·98
Fixed carbon	63·48
Ash	22·06

This seam strikes 117 degrees and dips 78 degrees to north. It is in another disturbed belt and though not much crushed a 3 foot seam only about 75 feet

higher up is crushed to powder, and was not sampled. What was thought to be the continuation of these seams was found in the saddle on Klappan mountain by Mr. Grossmann's party, and some pits were sunk on them.

On the mountain on the northern edge of the field, and just west of the east fork of the Klappan, two seams were measured. The lower has a thickness of nearly 3 feet, but is dirty. The other, separated from the first by a fault and probably representing the top of No. 3 group, has a thickness of 3 feet 3 inches and is apparently much cleaner. A picked sample taken from it was analysed by Mr. Wait with the following results:—

Moisture	4·14
Vol. comb.	8·43
Fixed carbon	80·27
Ash	7·16

Mr. Robertson also reports the analysis of a picked sample from the W. Pike seam which is as follows:—

Moisture	5·00
Vol. comb.	9·00
Fixed carbon	79·4
Ash	6·6

It seems probable that all the seams on Klappan mountain and in the vicinity belong to the No. 3 and No. 2 groups of the Skeena series, but the writer is not certain.

As the boundaries of the different holdings in the Moss Creek valley have not been run, the writer cannot discriminate between the different holdings there. On Campbell creek, which flows into Moss creek a short distance above Kluayetz lake, the writer found what is in all probability the same seam as the one into which the tunnel was driven near the mouth of Davis creek. It is in a disturbed condition, however, and so badly crushed that it was neither measured nor sampled. A short distance farther up (about half a mile from the mouth of the creek) the following seam was measured and sampled:—

Coal	3 feet
Bone	0·1 foot
Coal	1·1 feet
Bone	0·1 foot
Coal	1·9 feet
Total	6·2 feet

Total coal sampled, 6 feet.

Mr. Wait's analysis is as follows:—

Moisture	5·02
Vol. comb.	6·38
Fixed carbon	66·95
Ash	21·65

This seam strikes 77° and dips 34° 30′ to the north. It belongs to No. 3 group thrust over No. 2 group by the fault. Another similar fault occurs only a short distance above.

Higher up on Moss creek, just below the mouth of the next large creek from the west, another seam was measured and sampled and, also, a second near the head of this creek. The results for the first seam are as follows:—

Bone and dirty coal	3·85 feet
Coal (sampled)	5·05 feet
Bone	0·5 feet
Coal	0·2 feet
Total	9·6 feet

The 5·05 feet sampled contained the following:—

Quartz stringers and bone	0·1 foot
Quartz	0·05 foot
Quartz	0·04 foot
Bone with quartz stringers	0·3 foot
Bone	0·35 foot
Total	0·84 feet

So that of whole seam, 9·6 feet in thickness, only 4·21 feet were included in sample. Mr. Wait's analysis of this sample is as follows:—

Moisture	3·40
Vol. comb.	5·33
Fixed carbon	60·27
Ash	31·00

This seam strikes 112 degrees and dips 63 degrees to southwest. Possibly it is the same as the 50-foot tunnel seam on Trail creek.

The second seam near the head of the creek gave the following measurements:—

Coal	2·02 feet
Bone and dirty coal	2·01 feet
Coal	0·73 foot
Bone	0·43 foot
Coal	1·01 feet
Bone	0·45 foot
Coal	2·4 feet
Total	9·05 feet

Total coal sampled, 6·16 feet.

Coal on the Sustut.

As has been stated, the result of the writer's trip to the Sustut was the discovery of two seams of dirty coal, each 3 feet in thickness. A picked sample from the lower surface of the lower seam was analysed by Mr. Wait with the following results:—

Moisture	5·40
Vol. comb.	23·32
Fixed carbon	57·48
Ash	13·80

Mr. Geodfrey has told the writer that he found a 2-foot and a 4 foot seam in another part of the field, but was unable to furnish analyses. Since the above sample is from the surface and some of the surface samples from Groundhog resulted in somewhat similar analyses, viz., the 3 foot seam near summit of Jackson mountain, the analysis of which is as follows:—

Moisture	10·16
Vol. comb	23·73
Fixed carbon	45·79
Ash	20·32

it is not certain that the coal is a true lignite, as the analyses might prove had the sample been taken from a tunnel. The writer, however, is of the opinion that the coal is lignitic in character since the firmer portions of the seams gave a brown powder when struck with a shovel. As the conglomerates overlying the coal form a mountain ridge extending both to the northwest and southeast, it is evident that the field must be a large one, and as it lies on the probable route of a transcontinental railway north of the Grand Trunk Pacific, the author believes that it would be a suitable one for further prospecting. The approximate latitude of this field is 56° 15′ and the approximate longitude 126° 35′.

Kispiox Coal Field.

A day was spent at the Big Slide on the Skeena, where short tunnels had been driven in June and July on the different seams described in last year's report. However, it was found that all the seams were as badly crushed at the ends of the tunnels as they had been on the surface, and consequently they were not resampled. The measurements and analyses of the samples taken there are repeated from last year's Summary Report. The summary of the section is also given.

	Coarse sandstones and brown shales about	198 feet
1.	Coal	1·9 feet
	Brown shales and yellow sandstones	68 feet
2.	Coal	0·6 foot
	Bone and coal	0·9 foot
	Coal	1·3 feet
	Soft yellow sandstones and brown and yellow shales	169 feet

Fault of Unknown Throw.

3.	Yellow and brown shales	220 feet
	Coal	1·4 feet
	Bone	0·9 foot
	Coal	0·9 foot
	Bone	1·5 feet
	Coal	0·6 feet

The following are the results of Mr. Wait's analyses of samples omitting bone:—

	Moisture.	Vol. comb.	Fixed carbon	Ash.
No. 1	1·07	20·43	51·26	27·24
No. 2	1·19	10·33	64·77	23·71
No. 3	2·10	11·32	68·34	18·24

Mr. Leach has stated that on the Bulkley, the influence of the igneous intrusions has been to alter the coal towards an anthracite, and the fairly high percentages of fixed carbon in the seams may be explained as due to the presence of an igneous dyke only a few hundred yards to the south. The crushing which the coal has undergone has doubtless had the effect of increasing the ash content. As was stated in last year's Summary Report, the writer is of the opinion that there is an area of relatively undisturbed strata on the Kispiox near Kispiox post-office, and would expect that borings in that neighbourhood would reveal coal seams of superior quality, though he can offer no predictions as to whether they would be of workable thickness or not.

METALLIFEROUS DEPOSITS IN THE VICINITY OF HAZELTON B.C.

(*G. S. Malloch*)

Introductory.

The widespread nature of the mineralization in connexion with the Bulkley intrusives has been brought out in the Summary Reports of 1906 to 1910, and in the report on the district by the Provincial Mineralogist for 1911. There appear to be two main classes of ores which, however, in places, grade into one another. One group contains galena and zinc blende as the predominating ore minerals, and the other contains as predominate ore constituents, iron and copper minerals; in both cases the usual gangue is mainly of quartz. The veins of the first class often include galena, zinc blende, grey copper, arsenopyrite, stibnite, chalcopyrite, and sometimes native silver. The minerals in the second class of veins are pyrite, chalcopyrite, pyrrhotite, bornite, specular hematite, native copper, and some native silver. It must not be supposed, however, that the two classes are restricted to separate areas, for in the lower deposit of the Rocher Déboulé mine, 4½ feet on the foot-wall are mineralized with chalcopyrite, while on the hanging wall 2 feet of zinc blende and grey copper occur. The two portions of the deposit are separated by a dyke 3 feet thick. It seems probable that the two types have originated at different times in the same period of mineralization which probably followed closely the intrusions of the igneous masses.

Banded veins occur indicating by their structure successive periods of filling, and in such it is found that the chalcopyrite occurs at the edges as though first formed, arsenopyrite occurs midway towards the centre as though next deposited, while in the centre are found galena, zinc blende, and grey copper which appear to have been deposited last of all. This succession is especially strongly marked in vein No. 3 at the Harris mines.

The gangue mineral in the great majority of cases is quartz, and it was noticed that where much calcite occurs the veins are only sparingly mineralized. In the Rocher Déboulé mine, the gangue is composed of hornblende showing a radiate arrangement and accompanied by comparatively small quantities of quartz.

A feature which suggests a close connexion between the different types of mineralization throughout the district, is the regularity of the proportions of gold and silver values contained in the different minerals regardless of the mode of association of these minerals. Specimens of ore rich in galena usually show from 20 to 120 ounces of silver per ton, and only traces of gold. A specimen of nearly pure galena from vein No. 3 of the Harris mines gave: gold, a trace; silver, 111·5 ounces per ton. The highest silver values, however, are in the grey copper ores, specimens of which the writer heard had yielded 900 ounces of silver to the ton. A specimen of nearly pure grey copper was secured by crushing a specimen from the Harris mines, and yielded the following results when assayed by Mr. Turner of the Mines Branch: silver, 1,677 ounces; gold, 0·93 ounces. The arsenopyrite, on the other hand, seems to contain little silver but holds fair gold values. Specimens of the pure mineral from the Harris mines gave: gold, 0·32 ounces per ton; silver, none. A specimen of zinc blende yielded: gold, none; silver, trace. A sample of chalcopyrite and pyrrhotite with, probably, some pyrite, from the Rocher Déboulé mine, freed from gangue, yielded: gold, trace; silver, 1·69 ounces per ton. On the other hand, high silver values seem to occur with bornite. Mr. Robertson[1] quotes

[1] Report of Minister of Mines for British Columbia, 1911, p. 112.

an assay of ore containing bornite and chalcopyrite which assayed 112 ounces of silver to the ton and 60 per cent copper.

The connexion of the ores with the intrusion of the Bulkley intrusives is proved by the fact that all the deposits, so far as the writer knows, are either in the intrusives, along their borders, or in the vicinity of igneous dykes. It was also noticed in the case of the Harris and Silver Standard mines where the veins traverse the Hazelton group that the ore is much more highly mineralized in the vicinity of igneous dykes than farther away from them. These dykes appear to belong to the last phases of the eruption. They are porphyritic in texture and have altered the shales of the Hazelton group to hornfels for some distance on each side. The veins themselves are evidently a still later phase, for in many cases the veins occur in brecciated zones or along fault planes traversing the dykes and altered rock.

Description of Mines and Prospects.

Erie Group.

This group consists of four claims on Sixmile mountain, a semi-detached hill on the slope of Ninemile mountain which separates the Bulkley valley from that of the Shegunia river. The claims are situated about 5 miles from Hazelton and an aerial tram might easily be built to convey ore to the high-level road bridge now being built across the Bulkley. From this bridge a good grade can be obtained to the Grand Trunk Pacific at New Hazelton. A short description of this group was given by Mr. Leach in the Summary Report for 1909[1] under the title Era Group. Mr. Fleet Robertson has also described the group in the report of the British Columbia Minister of Mines for 1911[2].

The veins occur in a wide dyke of quartz porphyry along its northeastern side. The dyke cuts a large body of granodiorite. The old shaft has been abandoned for some years. During 1911 a vein was stripped for over 250 feet; it strikes 49° and dips about 70° to the southeast. This may be either the same vein as, or one nearly parallel to, the vein on which the old shaft was sunk. It lies to the southwest of the old shaft and is separated by about 500 feet of unstripped ground. From near the southern end of the 250-foot trench, a cross trench 125 feet in length and 10 feet in depth was cut, partly for the purpose of draining the main trench and partly to prospect the full width of the dyke of quartz porphyry in which the veins occur. The dyke is very sparsely mineralized throughout the length of the cross trench. The vein extends the entire length of the main trench, but appears to end at the southeastern end where the cross trench commences and in which the vein occurs only as a triangular mass on the north wall, and is entirely absent from the south wall, being cut off by a fault. The fault is indicated by a slickensided zone so that it is difficult to determine the dip and strike of the fault, but apparently it strikes more to the east than the vein and dips about 60 degrees to the north. In an inclined shaft in the main trench and some 30 feet from the cross trench the ore was followed down for some 40 feet where it abruptly disappeared and the rock below was granodiorite. On the surface the vein occurs in the porphyry and between it and the granodiorite, so that it seems likely that the fault is a normal one and the ore would be picked up by trenching at some distance south-southeast.

The gangue of the vein is quartz, but there are so many inclusions of both the porphyry and granodiorite that the whole represents a breccia zone rather than a

[1] pp. 66-67.
[2] pp. 102-103.

normal vein. The mineralization is strong at some places, but is bunchy. The chief minerals are coarsely crystalline zinc blende and fine grained galena, pyrite, arsenopyrite, chalcopyrite, and grey copper. Mr. Leach quotes the following analyses of specimens of ore from the old shaft, assayed by the Mines Branch, Department of Mines:—

	Gold.	Silver.	Lead.	Copper.
No. 1.......	0·08 ozs.	358·17 ozs.	7·81%	0·75%
No. 2.......	0·02 "	46·16 "	6·90%	0·26%

Mr. Robertson gives the analyses of a sample of the clean ore which gave 42 per cent of lead and 191 ounces of silver to the ton.

Harris Mines.

The Harris Mines, Limited, own eight claims on the southwestern slope of Ninemile mountain. A wagon road has been constructed up the valley of Twomile creek and a switchback horse trail has been constructed up the declivity to the different workings. These consist of a number of strippings on well defined veins, two shafts, and a tunnel. The uppermost vein, known as No. Three, has been traced on the surface for 600 feet and has an average width of about 2 feet. The general strike is 161 degrees and the dip to the northeast at from 50° to 80°. On the surface the vein is repeatedly offset for short distances by a succession of steeply inclined faults, striking about north and south. An inclined shaft 185 feet in depth along the slope has been sunk on this vein, and in drifts it was found that the striae on the fault planes point to a movement in an almost horizontal direction. For the greater part of its length the vein traverses the sandstones and shales occurring at the marine horizon in the Hazelton formation, but near the shaft at the surface a dyke of quartz porphyry occurs on the hanging wall of the vein, and on the foot-wall at the foot of the shaft. Since the surface is heavily covered, the exact relations of this dyke to the vein and country rock could not be made out. The strike of the sandstones is approximately parallel to that of the vein, but the dip is to the southwest at only about 15°. Both the sedimentary wall rocks and the dyke of quartz porphyry show the development of secondary calcite, but the gangue of the vein itself is almost exclusively of quartz. This vein shows a well-developed banded structure and, apparently, the different minerals have been deposited in a definite order. The amount of chalcopyrite along the borders of the vein is small, but there is a large amount of arsenopyrite in well-defined prisms set transverse to the direction of the vein. The central portion is filled with a number of bands of quartz impregnated with masses of galena and zinc blende which though irregular in size are sufficiently numerous to form roughly one-fourth of the total mass. Varying amounts of grey copper are also present associated with the galena and zinc blende and it appeared to the writer that the heaviest mineralization was in the vicinity of the dyke, though the development work done was not sufficient to definitely prove this. In 1911 a sample was taken across an ore-shoot 2·2 feet in width. It contained a large percentage of zinc blende and the values are not high: gold, 0·02 ounces; silver, 48·25 ounces per ton. In the autumn of 1912 when the writer visited the mine, 25 tons of hand-picked ore from this vein were being bagged preparatory for shipping to the Trail smelter. It is reported that the shipment netted $73 per ton above shipping and smelter charges. Grab samples taken of the ore, amounting to three pounds four ounces in weight and composed of small pieces, gave the following results on assay and analysis: gold, 0·04 ounces; silver,

128·58 ounces; lead, 31·80 per cent; zinc, 26·27 per cent. The analyses of the minerals separated from material derived from this vein have already been given.

Vein No. 4 is about on the strike of vein No. 3 and about 1,000 feet from the shaft. Much of the intervening country is heavily drift covered and the work on No. 4 consists only of a few open-cuts. The mineralization is very like that on No. 3 and one sheet of ore 16 inches wide was seen. A sample of the oxidized ore from the surface gave: gold, 0·32 ounces; silver, 58·17 ounces per ton.

Vein No. 2 is a couple of hundred yards southwest of No. 3. It differs from it in the total absence of chalcopyrite and arsenopyrite, and though mineralized with pockets of galena and zinc blende the quartz is completely barren for some distance. A subordinate amount of calcite was also found on this vein. No dyke of quartz porphyry was seen near this vein nor near No. 1 which is situated about 200 feet to the south. In No. 1 the mineralization is very similar to that in No. 2, but some chalcopyrite also occurs. The vein quartz sends out many irregular veinlets into the sandstones of the Hazelton group and in one instance a large horse is enclosed. A shaft was sunk on this vein to a depth of about 100 feet and a cross-cut showed rather more galena and blende than was exposed at the surface. Though the quartz was in places 3 feet in width the maximum width of any of the ore pockets did not exceed 18 inches. During the summer of 1912 the fifth vein, which may possibly be a continuation of No. 1, was discovered in the col to the east of the bunk houses. This vein showed about a foot of ore on the surface but flattened out at the depth of a few feet and then continued down with increased width. The mineralization resembled vein No. 3 and a coarse sandstone forming the wall rock was impregnated with calcite, and very likely an igneous dyke occurs in the vicinity. The percentage of grey copper present in this vein seemed greater than in No. 3, and this accounts for the higher values obtained from a picked sample taken from it, viz: gold, 0·05 ounces; silver, 347·13 ounces.

Silver Standard.

The Silver Standard group consists of six claims situated on a detached hill known as Glen mountain on the opposite side of the valley of Twomile creek from the Harris mines. The mine is reached by a wagon road from Hazelton which approaches it from the opposite or west side of the hill. The hill is composed of rocks of the Hazelton group which appear to be at about the same horizon as those at the Harris mines. On Glen mountain the sediments have been greatly affected by a number of dykes of quartz porphyry and often enough calcite has been developed in them to alter their colour from dark grey to white. Apparently they are nearly horizontal. In all, nine nearly parallel veins have been discovered which strike about 35° and dip at high angles to the southeast. The four veins which show the most mineralization are situated on the west side of the hill. Prospect work had previously been done on many of the other veins, but during 1912 the manager, Mr. Haskins, devoted his principal attention to sinking an inclined shaft which was begun about June, 1911, and which has now attained a depth of 285 feet. A cross-cut is being run to tap the next vein to the southwest and some drifting is being done on the vein in which the shaft was sunk. On the surface this vein can be traced for about one-fourth mile into the Surprise group but is narrow over most of the distance, having at many points a width of only about 6 or 8 inches. In the shaft the vein shows many changes of dip, and pinches and swells from only a few inches up to 6 or 8 feet at the maximum. The gangue is quartz and the minerals present are similar to those in vein No. 3 at the Harris mines; the usual occurrence of chalcopyrite and arsenopyrite near the borders was noted though the banding in this vein was not nearly so pronounced. In the autumn of 1911 the writer secured an

average sample across an ore-shoot 18 inches in width which assayed: gold, 0·38 ounces; silver, 317·42 ounces per ton; and in 1912 a picked sample from the bottom of the shaft gave: gold, 0·05 ounces; silver, 251·26 ounces.

The shaft seems to be near the border line between altered and unaltered sediments and it was noted that other workings on the property well within the altered country rock showed the presence of pyrite and arsenopyrite with only small quantities of galena, blende, or grey copper. The next two veins to the southeast seemed equally promising judging from indications seen in pits. The company has a large tonnage already bagged but is waiting for more favourable railway rates before shipping.

Rocher Déboulé Mine.

The Rocher Déboulé Mining Co. own six claims on the southern side of Rocher Déboulé mountain, and on the western slope of a glacial cirque draining to Juniper creek as the north fork of Kitsequecla river is designated. The mines are reached by a horse trail up this river which enters the Skeena a short distance below the railway bridge. Another horse trail extends from Sealey up the west slope of the spur separating the valley of Juniper creek from that of the Skeena, but stops at timber line; the rest of the journey over the crest of the ridge and down to the mines is necessarily made on foot.

There are three showings all of which are within the granodiorite which forms the central core of the Rocher Déboulé mountain. They are roughly parallel, striking about 65° and dipping from 50° to 60° to the northwest. While called veins the three showings are in reality mineralized dykes formed by the last phases of the eruption and consist of both acidic and basic phases of the granodiorite. Each showing consists of a parallel series of the acid and basic dykes and vein-like bodies. The basic phases are represented by dykes and vein-like bodies of rock composed chiefly of hornblende. Differential movements along these dykes have produced some fracturing and slickensiding and probably opened channels for replacing solutions. The uppermost showing was visible on the surface for about 150 feet and at one point a hornblende dyke had a width of 8 feet and had been very largely replaced by chalcopyrite, pyrite, and a little pyrrhotite. An inclined shaft was sunk to a depth of some 20 feet a short distance to the west of the widest part of the dyke but it was full of water when visited in October, 1912. The dump showed, however, that a large quantity of chalcopyrite had been taken out. A picked sample of the associated chalcopyrite, pyrite, and pyrrhotite freed from hornblende and quartz, was analysed with the following results: gold, trace; silver, 1·69 ounces; copper, 12·81 per cent.

In 1912 a drift was started on the dyke from a stream gulley, and a little ore was found at the start, but for over 150 feet the dyke was mineralized very sparingly. Just before the writer paid his visit, good ore had been struck and later reports indicate that a width of 6 feet was found farther on. A little native copper could be seen along the joint planes of the granodiorite adjoining the vein, but apparently only at the surface, so that it may be the result of secondary enrichment.

The middle dyke or showing has not been traced far and, where a pit was sunk, it hád a width of only about a foot, but the copper-bearing solutions had invaded the granodiorite and replaced the ferromagnesian minerals and quartz in it for a distance of several feet.

The third and lowest dyke can be traced for 700 feet and, where a shaft has been sunk, it has a total width of 7½ feet. This measurement includes a rib of coarsely crystalline granite porphyry 2 feet thick which divides the hornblende-bearing dyke into two parts, the upper of which is largely replaced by galena, zinc blende, and grey copper, while the lower half is less heavily min-

eralized with chalcopyrite and pyrrhotite. The mineralization with galena, zinc blende, and grey copper seems to be confined to a small lineal extent, for when the hornblende-bearing dyke was traced to the east, the only minerals seen were chalcopyrite and pyrrhotite, and moreover the dyke divides into a number of narrow stringers. To the west the continuation of this and the other two dykes is concealed by large angular blocks of granodiorite, which have apparently been plucked off from the higher part of the mountain by the glacier which eroded the cirque and placed them in their present position as a lateral moraine. The contact between the granodiorite, and the Hazelton group was found on the west side of this ridge and on the east side of Juniper creek. At both these points the contact was practically straight and if connected the line would pass only a short distance east of the points where the mineralized dykes pass beneath the lateral moraine. Along the contact much garnet and epidote and some tourmaline is developed in the sandstones of the Hazelton group and at certain points as, for example, on the Big Ohio group of claims opposite, the contact is mineralized with galena as well as with chalcopyrite, pyrrhotite and pyrite and specular hematite. This association of minerals suggests a type of contact metamorphic deposits which might improve at a comparatively shallow depth below the surface, and this seems to make it not unlikely that when the present dykes are traced eastward under the lateral moraine to the contact, more extensive deposits may be found. A picked sample of the galena, blende, and grey copper bearing portion of the lower dyke gave the following results on assay: silver, 126·4 ounces; gold, 0·06 ounces per ton.

Calcareous Spring Deposit.

Extensive deposits of calcareous sinter occur on both sides of the valley of Twomile creek and since no limestone occurs on the route of the Grand Trunk Pacific between Prince Rupert and Hazelton (and as far as the writer knows, as far east as Fort George and for some distance beyond), these deposits had attracted some attention. The writer took a fragment of this sinter. It was analysed by Mr. H. A. Leverin with the following results:—

Calcium carbonate	90·35
Magnesium carbonate	0·06
Ferric oxide and alumina	2·44
Sulphuric anhydride	0·01
Insoluble mineral matter	3·90

It will, therefore, be seen that if the deposits are uniform in composition with this sample they would yield a lime of average purity, while the porous nature of the material would render it particularly easy to burn.

A GEOLOGICAL RECONNAISSANCE OF THE FRASER RIVER VALLEY FROM LYTTON TO VANCOUVER, BRITISH COLUMBIA.

(*Norman L. Bowen.*)

Introduction.

The summer of 1912 was spent by the writer in a geological reconnaissance along the line of the Canadian Pacific railway from Lytton to Vancouver, a distance of 155 miles. The work constitutes a part of a complete section across the western Cordillera on which several field-parties have been engaged.

The chief problems to which attention was directed were those bearing on the structural geology, but at the same time many facts on the stratigraphy, physiography, and igneous geology of the area necessarily came to light.

The writer was efficiently assisted in the field by Mr. E. L. Bruce who carried on the work independently during the last few weeks of the summer.

Much valuable assistance was derived from the discussion of some of the problems with Mr. Charles Camsell, under whose supervision the work was undertaken. Only generalized statements can be made here. Detailed description of specific localities must await a final report.

General Character of the Area.

Throughout the part of the section here treated the railway line follows the valley of the Fraser river, a deeply entrenched valley which separates the Canadian Cascades from the Coast range. From Lytton the valley extends in a southerly direction for 66 miles; it then swings to a southwesterly direction for 20 miles, and finally to the west until it gains the coast. Lytton, at the northernmost end, lies toward the border of the Interior Plateau region of British Columbia with its dry climate and sparse vegetation, while the western part of the section has the moist climate and luxuriant forests characteristic of the Pacific slopes of the Coast range.

Summary of Results.

The more important results obtained may be briefly summarized as follows:—

(1.) The establishment of the fact that the Fraser valley from Lytton to North Bend follows a line of graben faulting.

(2.) Evidence obtained in the hanging valleys of side streams, of a dual erosion cycle.

(3.) Stratigraphic and palæontologic information on the Cretaceous.

(4.) Evidence bearing on the origin of the Fraser canyon.

(5.) Evidence of considerable post-Glacial erosion of bed-rock in the canyon.

(6.) The deciphering of a northeastward trending structure in the western part of the area, with the stratigraphy of the sedimentary rocks of that section.

(7.) The correlation of the course of the Fraser between Hope and Agassiz with this structure.

(8.) Very definite information on the relation of the batholithic bodies to the sedimentary rock invaded.

(9.) Facts bearing on the fluviatile origin of the Eocene sediments, and their relation to Eocene topography.

General Geology.

Table of Formations.

A general statement of the formations met with throughout the area is herewith presented in tabular form.

Quaternary—Till. Stream gravels, sands, etc.

Tertiary—Eocene grits, shales and conglomerates with lavas.

Mesozoic—Cretaceous fossiliferous shales, sandstones, and conglomerates.

Jurassic?—Batholithic masses of granite, presumably Jurassic.

Palæozoic?—Conglomerate, quartzite, shale and limestone with serpentine.

Pre-Palæozoic?—Gneiss.

Plan of Description.

Both for convenience of description and on account of fundamental structural differences it will be well to divide the area of the section into five distinct parts.

I. That portion extending from Lytton to North Bend in which bands of relatively soft rocks, in places Palæozoic schists, in other places, Cretaceous sedimentaries, have determined the valley direction.

II. The Canyon portion, extending from North Bend to Yale, where the river has cut a gorge in the firm granitic rocks of the Coast batholith.

III. That portion extending from Yale to Hope where the valley lies in a belt of intensely sheared granitic rocks.

IV. That portion extending from Hope to Agassiz where the valley direction is definitely related to structural lines of northeast-southwest trend.

V. The delta portion.

I.—Lytton to North Bend.

The rocks of this section may be described under the heads:—

Palæozoic schists.

Cretaceous conglomerates, grits, and shales.

Granite.

Rocks of one or both of the first two series, weathering in yellow and brown tones, commonly occupy the valley bottom and the lower slopes, while the more resistant grey to white granites form the upper slopes and the peaks and ridges beyond.

Benches and terraces of gravels and sands, with occasional true till, border both sides of the stream and in places the river bed is still in this material. The relations seen suggest that the glacier left the valley partially and very unevenly filled with morainal material which the river has since worked over, at first aggrading in places and degrading in others, and finally degrading throughout.

Many of the side streams, especially the smaller ones, have valleys which hang above the Fraser valley. This seems to be due only in small part to glacial overdeepening of the main valley. The great extent of the steepened portion seems to indicate rather a rejuvenation caused by general uplift and rapid erosion by the more competent Fraser.

Palæozoic.—The Palæozoics are chiefly silicified black slates with occasional beds of crystalline limestone, together with schists derived from basic igneous rocks. The average strike is N. 40° W., and dips are commonly at high angles approaching the vertical. The granite is plainly intrusive into this series. No fossil evidence of the age of the series was obtained but it is correlated on lithologic grounds with Dawson's Cache Creek.

With the Palæozoics is provisionally included the Boston Bar series of Selwyn, a series of slates banded in light and dark greys with occasional gritty limestones, having an average strike nearly north and south, and high dips. These are certainly pre-Cretaceous but may be post-Palæozoic. A single fossil, the only one known from the series, has not yet been submitted to a palæontologist.

Cretaceous.—The Cretaceous presents a great thickness of massive conglomerates, together with grits and shales. A collection of fossils from a heavy black shale member, upwards of 500 feet thick, has not yet been examined, but former collections from the same horizon have shown the series to be equivalent to the Shasta or Lower Cretaceous of California.

The average strike of the Cretaceous beds is about N. 15° W. and the dips are commonly at low angles, but close to the granites the attitude may be nearly or quite vertical. The granite does not, however, give any evidence of being intrusive. The relation shown is due to the down faulting of the Cretaceous beds. This part of the Fraser valley is, in fact, excavated along a belt of comparatively soft sedimentaries themselves preserved by graben faulting. The strips of Palæozoic rocks, too, probably owe their present position to this faulting, for the strike of their beds makes a sharp angle with the elongation of the strips.

The narrow belt of Cretaceous is probably continuous with the Pasayten of Smith, Calkins, and Daly, at the International Boundary.

Biotite Granite (Jurassic?).—The granite which forms the peaks and ridges is characterized by large greenish biotites. The term granite is used as a field name although it is probable that the microscope will show that the rock belongs with the granodiorites, so abundant in this general area. It is probably pre-Cretaceous in age, although the only observed contact with the Crecateous was a faulted one. It is certainly post-Palæozoic and may be placed with the other great Jurassic batholithic masses of the Coast range.

II.—The Canyon, North Bend to Yale.

General Character and Origin.—That portion of the Fraser valley extending from North Bend to Yale is characterized by steep rocky walls and an almost entire absence of drift filling, and is commonly known as the Fraser canyon. The grade of the river is much steepened, rapid follows rapid in quick succession, and these, together with the bare granite cliffs, contribute to the rugged grandeur that attracts the tourist to this section.

Throughout the greater part of the canyon both sides of the valley are of granite, but the southward continuation of the Palæozoic belt parallels the river, and nowhere is the contact with the Palæozoics far removed. Although so different in appearance from that part of the valley immediately to the north, it is probable that the mode of origin of the canyon is not greatly different. The river originally chose the weaker Palæozoic schists but, in the canyon portion, soon found itself let down upon the underlying firm granitic rocks where it continued to lower its bed. Relatively steep stream gradient and side slopes are but an expression of a graded condition in the very resistant material which the river must handle. Hanging valleys of the side streams are again well shown, indicating, as pointed out before, a dual erosion cycle.

Mr. Camsell has pointed out that certain features of the canyon indicate considerable post-Glacial erosion of the rock floor of the valley and further investigation seems to bear out this conclusion[1].

In places the present stream lies in a narrow notch upwards of a hundred feet below the somewhat broadened floor of the main valley as left by the glacier. In

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[1]Geol. Surv., Can., Summary Report, 1911, p. 108.

other places, too, comparatively frail rock columns, that could scarcely have withstood vigorous glaciation, stand up as islands in the stream 40 to 50 feet above its present surface.

General Geology.—The granite, so-called, is very variable in composition; and indeed, is not always granite, since syenitic and dioritic facies are common. The very variable nature is probably connected with the proximity of the batholithic contact. Besides the main body of granite, sometimes biotite-rich and sometimes hornblende-rich, there is a later intrusion of a porphyritic granite with prominent feldspars, which is quarried by the railway for use in bridge construction. Detailed description cannot be undertaken until microscopic work has been further prosecuted.

The Palæozoic belt which parallels the river, and locally cuts across it, is a continuation of the belt described in the area immediately to the north and need not receive special description at this point. The Hozameen series of Daly as described by him at the International Boundary, seems to be the southward continuation of this same belt.

III.—Yale to Hope.

Sheared Granite: Crush Metamorphism.—The valley of the Fraser between Yale and Hope, lies in a band of sheared granitic rocks. On both sides of the river, cliffs almost chalk-like in appearance are to be seen, but close examination reveals a much crushed and leached granite which crumbles quickly on exposure. In places the biotite of the original granite has become segregated in bands, often very evenly spaced, and, when viewed at a distance, strongly suggesting bedding. The 'dips' are commonly quite low and the whole aspect strikingly like that of some parts of the Shuswap terrane[1]. But no such evidence of a sedimentary nature as is continually furnished by the occasional limestone beds of the Shuswap is to be found here. On the contrary, the sheared variety is found to be transitional into ordinary gneissic granite with the biotite evenly disseminated. We have here a good instance of the transfer of material and the formation of a banded gneiss due to shearing, such as has received special description by Daly[2]. Some of this gneiss is post-Palæozoic, but whether all is or not has not been established.

Minor Exposures of Palæozoic and Cretaceous.—Rocks other than the biotite gneiss are comparatively unimportant in this area. In the valley of Gordon creek, which enters the Fraser about a mile south of Yale, a small patch of conglomerate, a band of rusty-weathering dolomite, and a considerable mass of serpentine are seen. To the west of the serpentine and intrusive into it, is an area of fresh, unsheared hornblende granite extending beyond the limit of the area examined. The hornblende granite extends southward about parallel to the river and again at Schkam lake, about a mile north of Hope Station, appears this peculiar association of conglomerate, dolomite, and a greenstone not unlike serpentine, lying along its eastern border. The dolomite and greenstone probably belong with the Palæozoics to the east of them, but the conglomerate is here seen to be part of a belt of Cretaceous rocks which cross the river at Hope station and make up the great mass of Silver peak. That the similarly associated Gordon Creek conglomerate is also Cretaceous there seems little reason to doubt, especially since, like the rest of the Cretaceous conglomerates, its pebbles are readily separated from their matrix. This small patch, although in itself quite unimportant, suggests, if it does not prove, a once continuous extension of a belt of Cretaceous rocks along the river from Yale to Hope.

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[1] Daly, R. A., Geol. Surv., Can., Summary, 1911, p. 168.
[2] Bull. Geol. Soc. Am., vol. 17, p. 344.

Besides the exposures incidentally mentioned above, Palæozoic rocks occupy both sides of the valley immediately above Hope and on a mountain northeastward from Hope, on the north side of the Coquihalla, can be seen forming a roof over the granite. The beds lie comparatively flat and receive numerous dykes and sills from the granite below.

IV.—*Hope to Agassiz.*

General Character.—The stretch of the Fraser valley lying between Hope and Agassiz, cuts in a southwesterly direction across granitic rocks and associated belts of Palæozoics, apparently without regard for rock structure. That there is probably no such disregard becomes apparent, when the area immediately to the west is examined. Here, structures with a northeast-southwest trend are very well exposed. These structures will be the subject of special description in a later section and in the meantime a few brief notes will be given on the area in hand.

The valley is characterized by a broad aggraded floor of stream gravels from which the rock walls rise steeply, with every evidence of glacial broadening.

Geology.—The granite exposed on both sides of the river, for several miles below Hope, is a continuation of that unsheared hornblende granite described in the section above Hope. Biotite is, in certain phases, a prominent constituent, but even in such cases the rock is not easily confused with the more altered granite, carrying greenish biotites, which is so widely distributed to the north and which probably belongs to an earlier period of intrusion. The hornblende granite cuts the Palæozoics, but further evidence of its age was not found. In the notch between Silver peak and White Cross peak, about 5,000 feet above the river to the south of Hope, highly disturbed Cretaceous rocks were found separated from the hornblende granite only by a patch of snow not more than 100 feet wide, which, however, effectually obscured any view of the exact contact. No dykes which could be considered as coming from the mass of granite were seen and it seems that the relation to this particular area of Cretaceous rocks is a faulted one.

At the mouths of Ruby creek, and of Walleach creek opposite, Palæozoic schists appear, only to be interrupted again by granite. The manner of this interruption is well exposed about 3 miles west of Ruby creek near the railway track. Northeastward-striking Palæozoics are sharply truncated by northwestward-striking intrusive granite with a steeply plunging contact.

V.—*The Delta Portion.*

Roughly speaking, the delta of the Fraser may be said to begin at Agassiz. A gradually broadening flat develops, most of which lies to the south of the present bed of the stream, and in which exposures of bed-rock are comparatively few. It was to bed-rock geology, however, that attention was chiefly directed. It should be mentioned at the outset that the examination of the section west of Mission was extremely hurried and practically limited to the few outcrops near the railway.

The chief general characters of this area are the appearance of Tertiary sediments and of an older fossiliferous series, preserving original characters in such a manner as to give very definite evidence as to their general structure.

Fossiliferous Sedimentary Series.—A thick sedimentary series overlies (whether unconformably or not, was not determined) an ancient gniess and is made up of a basal division of interbedded conglomerates and quartzites, followed by

slates, chiefly black in colour and often cherty, above which comes a heavy limestone member. The average strike is about N. 25° E. and the dip to the southeast averaging perhaps 30°.

The various horizons with the same succession and continuous strike can be recognized both to the north and to the south of the Fraser valley. The base is found near the gap where the Chilliwack river leaves the hills and turns northward to the Fraser, and again on the north side of the Fraser on the low mountain northwest of Agassiz. The upper limestone is found near Rosedale to the south, and on Bear mountain to the north,

A few poorly-preserved fossils were found in the slate division where this outcrops on the low hills that rise out of the Agassiz flat. They have not as yet been determined, but the series as a whole seems to correspond in general lithology with the Chilliwack series of Daly to the south where Pennsylvanian fossils have been found in both the slate and limestone divisions[1]. At the same time it should be noted that the series seems to lie on the strike of Daly's Cultus (Triassic), so that the question of age must, for the present, be left open.[2]

Later Intrusives.—Large batholithic masses of granite cut the fossiliferous series and their relationships are particularly well shown. Where the unroofing of the granite is rather far advanced, it appears as rather regular masses elongated in a northwesterly direction and, therefore, cutting across the strike of the sedimentary rocks. Beds are truncated sharply, but appear again on their strike, across a width of 2 or 3 miles of granite, quite as if no interruption had taken place. Where unroofing is still imperfect, granite occupies the lower slopes of the hills and is capped by the bedded rocks. These receive numerous dykes and sills from the granite beneath, but preserve their regional strike and dip. In short, there is shown the most absolutely convincing evidence of replacement, rather than displacement, of the sediment by the invading magma, such as has given rise to the marginal assimilation theory of the French school and to the stoping hypothesis of Daly.

Trend Lines.—The northeasterly strike of the fossiliferous series, together with the ancient gneiss, and the northwest strike of the granitic rocks, suggests that we are here dealing with Palæozoic mountains of northeast trend which experienced a period of faulting and intrusion in Mesozoic time. However this may be, there can be little doubt that in this northeastward strike lies the secret of the direction of the Fraser valley between Hope and Agassiz. Towards the east the granite becomes progressively more and more unroofed and sedimentary areas less well preserved, until finally both walls of the valley are of granite, but the valley-direction has been determined by bedded rocks now swept away. A northeast strike is still preserved by a small patch of Palæozoics in the mouth of the Coquihalla at Hope and in the schistosity of some of the gneisses between Hope and Yale. The possibility of the former extension of this ancient trend line far into the interior is suggested.

Quartz Porphyry.—A few exposures of a porphyry with large phenocrysts of quartz, and sometimes also of feldspar, are found in the area under discussion. A bluff along the railway track between Harrison Mills and Agassiz is made up of this rock in quite massive form. Division into definite sheets is not easily discernible but a columnar jointing indicates a dip of about 40° to the southwest. The writer had considered in the field that these volcanics belonged with the Eocene sediments, but Camsell finds that the latter are unconformable upon them at Sumas mountain, and suggests a Lower Cretaceous age for the quartz-porphyry. At Little mountain the rock is quarried for use as road-metal in and about Chilliwack.

[1] Daly, R. A., Geology of the North American Cordillera at the 49th parallel, p. 510.

[2] These fossils have since been determined by Dr. Stanton as indicating a Lower Cretaceous or Jurassic age.

Tertiary.—Tertiary rocks are exposed in widely separated patches in the flat lands of the Fraser delta. They consist of bedded rocks of Eocene age with which are associated volcanic rocks, most of which appear to overlie the sediments. Shales, sandstones, and conglomerates, all but little consolidated, make up the sedimentary series of which a total thickness of about 1,500 feet is exposed in Sumas mountain with a gentle dip of about 4° to the southwest. Here the shales are mined for brick-making, one particular bed of fireclay being especially desired. Its associated bed of lignite is sufficiently good to be used in firing the boilers of the hoist. Persistent cross-bedding in the sandstone and the pinching and swelling of beds give every evidence of a fluviatile origin.

Camsell has suggested that the Eocene rocks represent an ancient delta of the Fraser and with this the present writer is inclined to agree. The distribution and general character of the sediments seem to accord with the view that an Eocene delta roughly coincident with the present delta portion was built up at that time. Dawson's view that the relief of the Coast range in Eocene time was only slightly less than that at present displayed, is substantiated; moreover, a considerable amount of correspondence in detail is indicated, by the manner in which Eocene rocks enter the present re-entrants in the older rocks. Eocene rocks are now found as high as 1,000 feet above the present river.

Quaternary.—But little attention was given to the later deposits of the delta and only a brief note will be made here. The Fraser has cut into old deposits of gravels and sands with occasional tillite whose upper surface stands about 200 feet above the present river. Only small remnants of this deposit were seen, and these usually only where rock-defended, but, taken in connexion with reported raised beaches on the coast, they indicate, as has been pointed out by Le Roy[1], a level of the sea in late Glacial time some 200 feet higher than at present.

[1] A portion of the Main Coast of British Columbia, Geol. Surv., Can., No. 996, 1908, p 27.

GEOLOGY OF THE THOMPSON RIVER VALLEY BELOW KAMLOOPS LAKE, B.C.

(*Chas. W. Drysdale.*)

Introduction.

GENERAL STATEMENT.

During the field season of 1912, a 10-mile strip of territory along the Thompson valley between Sixmile point on Kamloops lake, and Lytton was geologically mapped and studied. The work was carried on for the purpose of extending the work of Professors R. A. Daly and J. A. Allan along the line of the Canadian Pacific railway in the eastern Cordillera westward to include the whole Cordillera from the plains to the Pacific coast.

A topographic base map was used upon which the geology was mapped by means of plane-table, and telemeter and compass traverses run along the main formational contacts. Three months were spent in field work. Mr. M. F. Bancroft rendered efficient service as field assistant.

The district included in the report is situated about 200 miles east of Vancouver along the main line of the Canadian Pacific and Canadian Northern Pacific railways, both of which follow the Thompson valley. The length of the region mapped in a northeast-southwest direction is about 74 miles and its average width is about 10 miles. The area included, therefore, is about 740 square miles.

The writer wishes to thank the residents of the region traversed, for their kind courtesy and interest, which aided considerably in the progress of the work.

HISTORY[1].

In the spring of 1808, Mr. Simon Fraser with Messrs. John Stuart, Jules Maurice Quesnel and a crew of 19 men and two Indians, started out in four canoes from Fort George, now on the line of the Grand Trunk Pacific, to explore the unknown waters to the south which were regarded then as the main tributary of the Columbia river. In June, 1808, they reached a large and rapid river flowing from the east. This was named Thompson river after David Thompson, astronomer to the North-West Company, who shortly afterwards founded Fort Kamloops. The Thompson river in later years became known the world over through a series of great gold rushes. The first gold discovery in British Columbia is said to have been made by an Indian in this district at the junction of the Nicoamen river with the Thompson, about 10 miles above its mouth. The Indian, while stooping to drink, saw a large nugget glittering in the water. He picked it up and brought it in to Mr. McLean, the officer in charge at that time of Fort Kamloops. The Nicoamen locality was noted for its coarse gold, but the supply was soon exhausted.

In 1857, it is said that the Hudson's Bay Company had received from October 6 to the end of the year, 300 ounces of gold, through their agent at the Thompson and Fraser rivers.

[1] The reader is referred to the following works for more detailed accounts:—
The works of Hubert Howe Bancroft, vol. XXXII, History of British Columbia, 1792-1887.
Begg, Alexander, History of British Columbia, 1894.
Mayne, R. C., Four Years in British Columbia and Vancouver Island, 1862.

About this time, the region was becoming known abroad through its placer gold discoveries, and prospecting parties travelled north from Oregon and Washington territories in quest of the precious metal. Some of the gold seekers entered British Columbia by way of Colville and made their way to the junction of the Thompson and Fraser rivers where they found several rich bars, which were worked successfully.

The great rush, however, did not take place until 1858. In the spring of that year the whole country was a scene of great excitement. Hundreds from the northern counties of California 'trecked' northward with their pack trains and cattle trains by the interior route via Okanagan and Kamloops. They found it necessary to travel in large companies for protection against Indians. When the cattle trains reached their destination, the oxen were sold for beef. In May, June, and July, of 1858, over 30,000 people migrated northward into British Columbia, but before January 1859, they had all returned to the United States, with the exception of about 3,000.

The aggregate yield through placer mining along the Thompson and Fraser rivers for the years 1857, 1858, and 1859 alone, amounted to not less than $1,700,000[1]. This mining was conducted on river bars and benches with the aid of rocker and sluice box. The gravel and boulder deposits generally capping the river terraces and the recent river gravels were found most productive of gold. Since 1859, little mining on a large scale has been done in this district. In September 1860, 200 Chinese were digging near the mouth of the river, and in the autumn of 1861, 150 miners were reported at work making $16 per day near Tranquille river on the north shore of Kamloops lake. The famous 'Cariboo rush' began in 1860 and lasted until 1862. This resulted in 1862 in the building of trails and a wagon road to make the rich Cariboo region between the head-waters of the main Fraser and Thompson rivers, accessible to prospectors and miners.

The old trails and wagon roads were built at great expense through the Thompson valley and are still used considerably as highways. The first sod was turned on the Canadian Pacific railway early in 1880 and the road was open for traffic in 1885. The Canadian Northern Pacific commenced construction work in the spring of 1911 and will shortly be open for traffic.

CLIMATE AND AGRICULTURE.

The climate of this region, which is commonly known as the Dry Belt of British Columbia, is most delightful. The scanty precipitation of the district is largely due to the intermontane position it occupies between the Coast range on the west and the Gold ranges on the east. The westerly moisture-bearing winds are partly arrested by the western barrier and become desiccated before they reach the district. The higher air currents touch upon the green grassy upland tracts, with scattered trees, which receive more moisture than the deeply entrenched valleys which are largely devoid of timber but support much bunch grass and small sage. Where irrigated, however, the valley flats support good crops of vegetables and fruits. The upland country is good for grazing purposes and the production of timber.

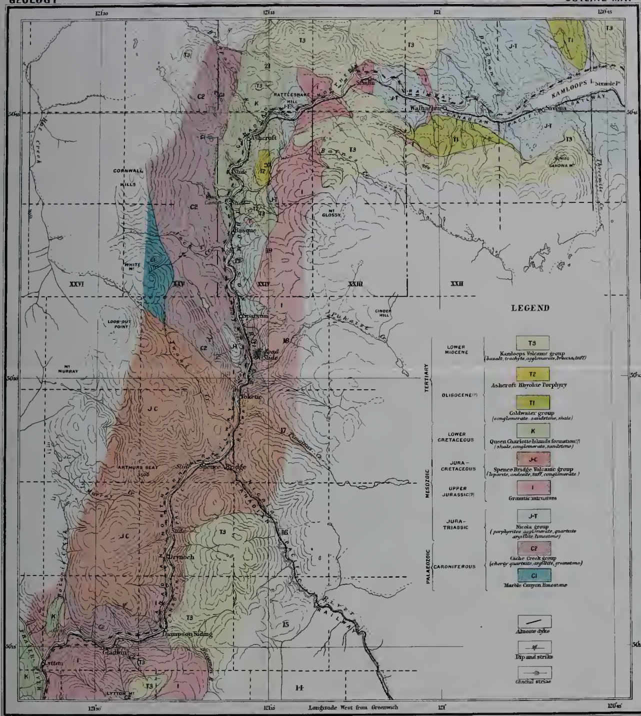
The following statistics have been kindly supplied by the Dominion Meteorological Bureau:—

[1] Dawson, G. M., Report on Kamloops Map Sheet, vol. VII, 1894, p. 326B.

Canada
Department of Mines
Hon L Coderre, Minister A P Low Deputy Minister
GEOLOGICAL SURVEY
R W Brock Director

GEOLOGY

OUTLINE MAP



C-O Senecal, Geographer and Chief Draughtsman

MAP 104 A
(Issued 1913)

THOMPSON RIVER VALLEY BELOW KAMLOOPS LAKE, BRITISH COLUMBIA

Scale of Miles

To accompany Summary Report by C W Drysdale 1912

	Mean annual rainfall inches.	Mean annual snowfall inches.	Total mean annual precipitation inches.	Highest temperature		Lowest temperature		Mean annual temp.
				Deg.	Year.	Deg.	Year.	
Kamloops.....	7·56	27·34	10·30	102·4	1906	–26·9	1899	47·34
Kamloops in 1910........	5·61	20·75	7·69	96·5		–8·6		48·50
Douglas lake..	....	....	9·34	......		......		......
Cache creek...	....	....	11·20	......		......		......
Spence bridge.	....	....	7·68	......		......		47·4

WATER POWER.

The Thompson river, which drains an area of 21,800 square miles, has an average gradient between Kamloops lake and its mouth at Lytton of approximately 0·18 per cent, or a drop of about 9½ feet per mile. The grade, however, is not uniform and certain stretches have quite a gentle gradient. Between Thompson Siding and Lytton, the river falls 200 feet.

In the autumn, the river carries from 15,000 cubic feet to 20,000 cubic feet of water per second. The water is highest during the month of July. The range between high and low water is great, amounting in places to as much as 40 feet.

The minimum figure, estimated for the available water-power between Thompson and Lytton, has been placed at 100,000 horse-power[1].

FLORA AND FAUNA.

The main species of trees are: Douglas fir (*Pseudotsuga douglasii*), yellow pine (*Pinus ponderosa*) and in the dry Alpine country the white-barked pine (*Pinus albicaulis*). The valleys are comparatively clear of wood, except along the banks of streams which traverse them, and on which there is ordinarily a growth of willow and alder. The trees in many places follow the draws or dry gullies where the ground water level is close to the surface.

A number of interesting animals inhabit the district; among these are black-tailed deer (*Cariacus mecrotis*) and, not so commonly, the white-tailed deer (*cariacus virginianis*); black bear (*ursus Americanus*) occasionally occur and at the western edge of the district in the vicinity of Lytton mountian, grizzlies (*ursus horribilis*) have been seen. Coyotes (*canis latrans*) are fairly common in the valleys. Rattlesnakes mainly inhabit the lower and dry valleys, and are common.

PREVIOUS WORK.

The first important geological work was done in this district in 1871 by Dr. R. C. Selwyn, Director of the Geological Survey, and Mr. James Richardson who made a reconnaissance trip from Yale, on the Fraser river, to Kamloops. The following classification of the rocks in the Province was based upon this exploratory work:—

I. Superficial deposits.
II. Volcanic series and coal and lignite group of the mainland and the coal rocks of Vancouver island.
III. Jackass Mountain conglomerate group.
IV. Upper Câche Creek group (Marble Canyon limestone).
V. Lower Câche Creek group.

[1] Water-powers of Canada, 1911. Report of Commission of Conservation, pp. 321, 326.

VI. Anderson River and Boston Bar group, and upper rocks of Leather pass and Moose lake.
VII. Cascade Mountain and Vancouver Island crystalline series.
VIII. Granite, gneiss, and mica-schist series of North Thompson, Albreda lake, and Tête Jaune Câche, including the micaceous schists of the Cariboo district.

During the field season of 1877, Dr. G. M. Dawson made a reconnaissance survey along the main routes of travel through the southern portion of the interior of the Province. As a result of this work a preliminary report and map were published in the Report of Progress of the Canadian Geological Survey for 1877-78.

In 1899 and 1890 Dawson's work was confined to the northwestern quarter of the old map, of which the scale was doubled, making a map of the same size as the first but covering only one-fourth of the original area. The topography was revised by Mr. James McEvoy. The result of this more detailed examination of the district appeared in Dawson's 'Report on the Area of the Kamloops Map-Sheet'[1].

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[1] Annual Report of Progress, Geol. Surv. of Can., New Series, vol. VII, 1894.

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Summary and Conclusions.

PHYSIOGRAPHY AND PHYSIOGRAPHIC HISTORY.

The district along the Thompson river between Sixmile point on Kamloops lake and Lytton, falls within the physiographic province known as the Interior Plateau. This belt is characterized by many flat-topped or gently undulating upland surfaces separated by deeply entrenched valleys (from 3,000 to 5,000 feet deep).

The main Thompson valley is, as a rule, partially filled by several hundred feet of fluvio-glacial materials which have been carved by the meandering river into broad fertile river terraces. The present river channel is in a gorge deeply incised in the valley-fill material and even deep into bed-rock itself as is the case at the Thompson and Black canyons.

The main tentative conclusions derived from a study of the physiography of this and neighbouring regions are as follows:—

(1.) The Thompson and Fraser rivers are antecedent streams whose courses transverse to the regional structure have persisted from courses developed during a Cretaceous erosion cycle.

(2.) In the Coast range the advanced stage of dissection which has left only accordant summit levels and a few possible plateau remnants suggests that the former land surface was an uplifted erosion surface of an earlier age rather than of Tertiary age.

(3.) Tertiary erosion did not bring the Coast range down to a peneplain as it did many portions of the then low-lying Interior Plateau. The Tertiary erosion surface in the Coast range had only reached a mature and post-mature stage of topographic development prior to uplift.

(4.) The upland surfaces of the Interior Plateau represent glaciated remnants of a late Tertiary peneplain.

(5.) During a pre-Miocene erosion cycle the way was prepared for the more complete late Tertiary cycle and the former was responsible for the removal of much of the early Tertiary rock record.

(6.) The deep youthful valleys entrenched beneath the upland with broad terrace-steps represent the work of erosion and sedimentation due to both water and ice, since the late Pliocene uplift.

(7.) Post-Glacial erosion, invigorated in part by recent elevation, is responsible for the canyons, gorges, and land slides so prevalent throughout the district.

(8.) The present topography may be said to have been dominantly developed during Pliocene and later erosion cycles.

GENERAL GEOLOGY.

The district under consideration includes an unusually good record of sedimentary, metamorphic, and igneous rocks ranging in age from Carboniferous to Recent. Among the bed-rock formations the Mesozoic and Tertiary have by far the widest distribution.

The Carboniferous formations (Câche Creek group) consist of very highly metamorphosed, marine sedimentary and eruptive materials. They outcrop in the central portion of the district, as cherty quartzites, argillites, greenstones, and crystalline limestones (Marble Canyon limestone)—the latter apparently the youngest, although in many places the marble is intimately interfolded or interbedded with the older members of the group.

There are four distinct Mesozoic formational groups, namely: Jura-Triassic (Nicola group), upper Jurassic (granitic intrusives), Jura-Cretaceous (Spence Bridge Volcanic group), and Lower Cretaceous (Queen Charlotte Islands formation.)

The Jura-Triassic rocks are chiefly altered eruptives (diabasic in composition) of both flow and fragmental type, with included argillaceous, arenaceous and calcareous beds. The upper Jurassic rocks which occur as batholiths, stocks, and tongues are made up of granular intrusive rocks varying from granite to granodiorite and diorite, and are all subalkalic in composition. The Jura-Cretaceous rocks consist of over 5,000 feet of liparitic and andesitic lavas with interbedded tuff, agglomerate, and conglomerate beds. The Lower Cretaceous rocks are carbonaceous shales, sandstones, and conglomerates.

There are two distinct Tertiary formational groups in the district which are of Oligocene (?) or possibly Eocene (Coldwater group, and Ashcroft rhyolite porphyry) and of Miocene (Kamloops Volcanic group) age.

The Oligocene (?) rocks consist of indurated continental sediments, which include remnants of coarse, river and lake conglomerates, sandstones, and shales. Under the Oligocene (?) is also included a rhyolite porphyry formation capping a

hill in the vicinity of Ashcroft. The Miocene (lowest) consists of basalts (both amygdaloidal and vesicular types), agglomerates, breccias, and tuff beds with smaller quantities of younger mica andesites and various porphyrites, the whole group approximating 3000 feet in thickness.

Deposits of Pleistocene and Recent age are very plentiful and consist of Glacial till, gravels, sands, clays, and silts.

During the past field season fossil plants were found near Spence Bridge in the tuff beds belonging to the Lower Volcanic group as previously mapped (Miocene of Dawson's Kamloops map sheet), which on identification place the group in the Jura-Cretaceous instead of the Miocene. On this account and because the town of Spence Bridge is situated near the centre of this broad belt of chiefly volcanic rocks the writer feels justified in changing the name from that of Lower Volcanic group to *Spence Bridge Volcanic group.*

More detailed field work is needed to extend and delimit the Spence Bridge Volcanic group to the north and south. As a result of such work it may prove necessary to include in the Mesozoic over 400 square miles of territory at present mapped as Tertiary. The structural relations of this group with both older and younger formations require examination. No contacts between the Spence Bridge group and the Queen Charlotte Islands formation were observable within the limits of the railway belt examined last season.

It has further been deemed advisable in the Kamloops Lake vicinity to include both the Lower Volcanic group (which bears no resemblance to the Spence Bridge Volcanic group), and the Tranquille beds, with the conformably overlying Upper Volcanic group of Dawson and to call the whole series by the new term *Kamloops Volcanic group.*

Collections of invertebrate fossils from some hitherto undescribed localities within the Nicola group (Jura-Triassic) area were made. Dr. T. W. Stanton reports:....'that the general character of the fossils, with possibly one or two exceptions, indicates that the rocks are Jurassic and it is possible that some, or all, of them may be Lower Jurassic.

ECONOMIC GEOLOGY.

The main economic mineral resources of the district include low grade gold placers, mercury ore, copper ore in small quantities; much clay suitable for brick making; limestone suitable for the manufacture of lime; and agates and chalcedony of fair quality for ornamental purposes.

Physiography and Glacialogy.

GENERAL ACCOUNT.

The western British Columbia Cordillera is broadly divided into the Coast range fringing the Pacific ocean and an eastern belt known as the Interior Plateau. The Coast range, whose summits rise to altitudes of from 8,000 to 9,000 feet, is bounded on the south by the Cascade range which ends at the Fraser river and Lytton and on the east by the Fraser river. East of the Fraser river above Lytton and east of Chilco lake to the north, extends the Interior Plateau Belt[1] characterized by many broad flat-topped hills whose elevations range from 3500 to 5000 feet, with deep intervening valleys.

[1] Daly, R. A., The Nomenclature of the North American Cordillera: Geog. Jour., vol. XXVII, 1906, p. 588

The map-area includes that portion of the broad and deep valley of the Thompson river which traverses the Interior Plateau from the centre of Kamloops lake where it is over 6 miles wide and 3500 feet deep, to its terminus at Lytton, where the valley narrows to about 3 miles and is more than 5,000 feet deep.

The lower stretches of the valley are characterized by the presence of wide fertile terrace steps, composed of fluvio-glacial materials, rising from 30 feet to 1000 feet above the level of the river. Upon such bench lands, fruit and vegetables are grown extensively by the aid of irrigation. Where the land is not under cultivation, sage brush and cactus abound. The terraces and steep valley slopes are cut by innumerable small gullies and ravines which are generally dry.

There is comparatively little bottom land near the river which flows, as a rule, in a narrow winding gorge incised deeply in the alluvial bench lands and in places even deeply into bed-rock itself. The Upper and Lower Black canyons and the Thompson canyon furnish good examples of down-cutting in bed-rock.

Above the terraces, the valley slopes rise rather abruptly in rocky ledges and escarpments up to an elevation of approximately 3500 feet in the eastern portion of the district and 5000 feet in the western. At this elevation a pronounced change of slope is reached, and instead of bare rocky slopes and rock knobs, there prevails a more gently undulating type of topography. The woods are open and park-like and on the green grassy hills are many different types of wild flowers. Here and there are depressions occupied by lakes and stagnant pools, leading down to which are many cattle paths. The upland tracts afford good grazing ground for cattle and stand in strong contrast to the semi-arid lands of the deep youthful valleys with their steep rocky upper slopes, and flat, fertile, fluvio-glacial terraces beneath.

DETAILED ACCOUNT.

Physiography deals not only with the configuration or shape of the landscape as we see it to-day, but also with the manner of its development and origin. In this detailed section, it will be attempted to systematically assemble and discuss the data bearing on the genesis of the land forms and the conclusions derived from their study. Such discussion, which will include a genetic classification of the land forms in the district, must necessarily be based on a comprehensive knowledge of the facts of the geological history. Sedimentation, vulcanism, and diastrophism of the past have all left their impress to a greater or less degree upon the present topography. For facts bearing on the geological history the reader is referred to a later section of this report and for the geological details upon which the conclusions regarding the geological history are based, he may refer to the section on General and Structural Geology.

The field data will be classified under the main headings of:—

(*a*) Data bearing on erosion cycles and glaciation.

(*b*) Data bearing on drainage combined with outline of drainage history.

It will be noted that the topography of the district has been greatly influenced by topographic forms developed during previous erosion cycles, mainly by those of late Tertiary age which have been modified by differential uplift and glaciation. The influence of bed-rock structure is of minor importance. Where bed-rock structure does dominate the topography, as for instance in the vicinity of Spatsum, it is interesting to note that it does this in the youthful valleys below the old upland surface.

(*a*) *Data Bearing on Erosion Cycles and Glaciation.*

Owing to the dry climate in this portion of British Columbia, the sets of physiographic forms resulting from the late Tertiary and Quaternary erosion cycles

can be clearly seen and are separated by sharp topographic breaks or unconformities.[1] Three main sets have been distinguished and they will be discussed in the following order commencing with the oldest:—

(1) Old upland erosion surface.
(2) Youthful valleys.
(3) Post-Glacial erosional forms.

(1) *Old Upland Erosion Surface*.—From the summits above 3500 feet in elevation in the eastern and 5000 feet in the western portion of the district, may be seen broad remnants of a gently undulating upland which embraces many square miles and extends for about 100 miles in width between the Columbia mountains on the east and the Coast range on the west. Northward the upland is probably continuous with that of the Yukon plateau. The upland surface merges both to east and west into the more mountainous topography of the bordering ranges. Rising above the general level of the upland are residual hills (monadnocks) and highland masses which have withstood erosive agencies and have been left standing above the old surface. The most prominent residual ridges are composed of crystalline limestone (Marble Canyon limestone) and on account of their whiteness are conspicuous as, for instance, the ridge west of the Thompson valley between Ashcroft and Spatsum, and those of the Pavilion and Marble mountains farther north.

Generally the upland summit level grades down toward the axis of the major streams, whose valleys, as will be indicated later on, probably occupy positions inherited from the previous erosion cycle. This upland erosion surface bears no relation to underlying structural features and truncates or bevels tilted volcanics of lower Miocene age (Kamloops Volcanic group). This is well shown on Savona mountain, Hardy mountain, and elsewhere.

The upland slopes are thickly mantled with morainic drift and glacial erratics. Bare surfaces of rock show evidence of continental glaciation in the presence of glacial striæ with average strike of S. 35° E. The valleys of the upland, however, in contrast to the younger deeply entrenched valleys within it, do not show evidence of having been powerfully glaciated, as, for example, by the presence of deep scoring and glacial plucking.

From the above facts concerning the upland erosion surface, it may be inferred that they are in the main glaciated remnants of an uplifted gently undulating surface developed during a later Tertiary erosion cycle because lower Miocene volcanics are truncated. Later than the uplift which possibly occurred in late Pliocene time[2] the erosion surface has been dissected by the youthful valleys.

Previous erosion cycles have no doubt influenced to some extent the degree of perfection of this late Tertiary erosion surface. The surface as viewed from the upland grades gradually into the high bordering mountains where it gives place to the more mountainous topography of the ranges which, prior to Pliocene uplift, had reached only a mature or late mature stage of development. Since uplift, it has been further carved by deep V-shaped valleys and well sculptured by alpine glaciers. It appears as if this uplifted mature or late mature upland surface was the result of the dissection of a still older erosion surface, probably of Cretaceous age. The deep glaciated valleys cut below the Tertiary upland, represent erosion since the late Pliocene uplift.

An alternative hypothesis favoured by many[3], is that the Coast range represents an upwarped and dissected late Tertiary peneplain. The axis of the Coast range, which had been a locus of previous disturbances, was uplifted higher than the

[1] Salisbury, R. D., 'Three New Physiographic terms,' Jour. Geol., vol. XII, pp. 707-715 (1904).
[2] G. M. Dawson: Bull. Geol. Soc. Am., vol. XII, 1901, p. 90.
[3] Spencer, A. C.: Pacific Mountain System in British Columbia and Alaska, Bull. Geol. Soc. Am., vol. 14, 1903, pp. 117-132.

interior region, so that while the latter preserved to a large extent its plateau character the Coast range, by reason of the greater relief, was extensively dissected and thus became the present rugged, irregular mountain mass, which has preserved its plateau features only in the even crest lines.[1]

From the facts bearing on the glaciation of the Interior Plateau it may be inferred that during the Pleistocene it was overridden by the Cordilleran ice sheet moving in a general direction of about S. 35° E., which considerably modified the upland topography, and on its retreat left much morainic material. No evidence as to the probable depth of the Cordilleran ice cap over this section of the country could be obtained.

(2) *Youthful Valleys.*—Beneath the old upland are entrenched deep valleys with steep sides. The main one is the Thompson valley which narrows and steepens on approaching the Coast range to form the Thompson canyon. From the main Thompson valley many steep-sided tributary valleys extend back for many miles and gradually grade headwards into the upland itself.

The valley slopes show evidence of more intense scouring and plucking action by glaciers than do the upland slopes.

The bottom lands are flat and consist of a series of broad step-like river terraces cut out of fluvio-glacial materials. The terraces display sharp points between concaved reaches, the result of former meandering of the stream. The lower meanders have in many cases cut out older terraces at higher levels and a high terrace ends abruptly at a single escarpment at whose base the river is busy undercutting. This is well illustrated at Walhachin a town located on a high terrace overlooking the river.

For convenience in describing the various valley features of the district, this strip of territory along the Thompson valley may he divided into three general sections which grade into one another. The eastern section is characterized by a deep broad valley with an uneven rocky floor at present occupied by Kamloops lake, whose average depth is 300 feet. Along the valley sides may be seen truncated spurs, small tributary hanging valleys or rock niches with alluvial fans and deltas built out into the lake. The main valley itself is comparatively free from broad flats. There is, however, south of Savona near the west end of Kamloops lake at an elevation of about 2000 feet, a conspicuous flat underlain by resistant Triassic rocks which protrude in places above the general level forming rocky knolls. In the depressions upon this flat there are numerous alkali lakelets and stagnant pools. Lying upon this rock floor and in an early Tertiary valley eroded within it, are slightly deformed chiefly coarse-grained sediments with a general east and west trend capped and protected from erosion by lower Miocene volcanics. The early Tertiary sediments form prominent strike ridges. The volcanic rock cliffs have been considerably retrograded and as a result, high precipices with outstanding pinnacles or 'hoodoos' and talus accumulations skirting their base are common features to be seen on the high rocky slopes of the valleys. In some localities, where the country which is semi-arid is underlain by fine-grained flat-lying tuff beds of varying resistance (Tranquille formation), 'bad land' topography results with the development of innumerable drainage lines upon the valley slopes.

The central section extends from the west end of Kamloops lake to Thompson siding, a distance of 59 miles. It is characterized by a great depth of fluvio-glacial material, beautifully terraced by the meandering Thompson river. The deeply incised river, however, has only in a few places reached bed-rock. The terraces rise from 30 to 400 feet above the river, and the terrace steps slope gently toward the river and have as a rule near their surface a coarse bouldery layer of river origin, the boulders overlapping one another with their longer diameters in the direction of flow.

[1] Brooks, A. H., Geography and Geology of Alaska, U.S. Geol. Surv., P.P. No. 45: p. 271.

A till sheet underlies in places cross-bedded gravels and sands which in turn are covered by a still younger till sheet. The tills, gravels, sands, and silts interfinger and are in places difficult to separate from one another. A clay silt, well bedded, and of considerable thickness is very persistent throughout the valley at about the same general elevation. Where the river has cut into the white silt banks and boulder clay to form cliffs, 'hoodoos' or pinnacles of this material stand out in prominence.

The deltas at the mouths of tributary streams consist largely of coarsely cross-bedded gravels and sands. The delta of Barnes creek near Ashcroft appears to have forced the Thompson river to cut into its north bank composed of silts, sands, and gravels. As a result the silt cliffs are becoming rapidly retrograded and only a narrow stretch of terrace land now fringes Rattlesnake hill.

Esker-like ridges occur on the higher valley slopes east of Spatsum in the central portion of this section. In the same vicinity bordering the North and South Thompson valley may be seen a prominent limestone mountain, the limestone having a north-northeast and south-southwest trend and dipping steeply toward the centre of the valley and controlling the topographic form.

The western section from Thompson Siding to Lytton—the Thompson canyon proper—displays a very mountainous appearance in bold contrast to the eastern section. Here the mighty Thompson river has deeply incised itself through the fluvio-glacial materials well into bed-rock, forming a deep canyon. The canyon contains many huge blocks of rock that have tumbled from above, and are now in process of being broken up and carried down stream by the turbulent river.

The south slope of the valley is well wooded and very steep. The north slope is more open and park-like but is sharply scarped in places where the river has undercut it. The tributary creeks have incised deep ravines near their mouths which contain much coarse talus material tumbled down from the cliffs above. A few miles above Lytton, there is a prominent scarp known as the 'Crag', which would appear to have been formed by comparatively recent faulting along the trend of Botanie Creek valley.

From the above facts regarding the valley features it may be inferred that the present valleys are youthful and the product of an erosion cycle following the late Pliocene (or early Pleistocene) uplift, and including at least two advances of valley ice. The second advance of the valley ice may have taken place at the time of the maximum extension of the Keewatin ice sheet to the east.[1]

In the eastern section glaciation was mainly erosional resulting in glacial deepening and widening of valleys. This combined with the impounding effects of the Deadman Creek delta brought about the formation of Kamloops lake. On the north side of Kamloops lake, glaciation has produced truncated spurs, hanging valleys or rock niches, whereas on the south side, the tributary streams have built out large alluvial fans and deltas, since dissected and terraced.

The central and western sections were dominantly belts of aggradation in contrast to the eastern section of degradation. The valley glaciers acted here in a constructive manner, and heaped up great thicknesses of valley train materials since excavated by the meandering river into broad terrace flats. The river terraces

[1] The eastward succession of the continental ice sheet has been pointed out by J. B. Tyrrell and G. M. Dawson, who found that the Cordilleran glacier reached its greatest extent and retired before the boulder-clay that generally underlies the western plains was deposited. This boulder-clay, Mr. Tyrrell takes to be the true till or ground moraine of the Keewatin glacier when the glacier had reached its greatest southwesterly extent.

Tyrrell, J. B., The Genesis of Lake Agassiz, Jour. of Geol., vol. IV, 1896, pp. 811-815.

Dawson, G. M.: Glacial Deposits of Southwestern Alberta in the vicinity of the Rocky Mountains: Bull. Geol. Soc. Am., vol. VII, pp. 31-66, Nov., 1895.

Calhoun, F. H. H. : The Montana Lobe of the Keewatin Ice Sheet: U.S. Geol. Surv., P.P. 50 (1906), p. 56.

have been influenced a great deal in their development by protective rock shoulders or spurs. As the river, swinging from side to side, slowly degraded its valley floor it encountered rock ledges projecting from the sloping valley wall. The deeper the valley floor was excavated the less breadth of free swing the river had. Westward where the Thompson valley narrows and steepens the river does not have as many meanders. With this straightening of the river course the terraces become narrower and the river cuts through them to form a canyon in bed-rock.

(3) *Post-Glacial Erosional Forms.*—Beneath the youthful valleys are cut secondary small valleys or canyons and gorges varying from 60 feet to 400 feet in depth and 300 to 400 feet wide. In the gorges and canyons there is comparatively little bottom land, and the river occupies nearly the whole width of its valley. In places, as at the Black canyon and Thompson canyon, the river has cut deep into bed-rock and the tributary creeks have in many places cut deep V-shaped ravines. These younger gorges and ravines show no evidence of glaciation.

A prominent rock slide may be seen on the east side of the Thompson valley opposite 89-mile stable a few miles north of Toketic. The structural relations there were favourable for a rock slide in that an outlying mass of altered sedimentary and eruptive rocks (Mesozoic), striking parallel to the valley and dipping towards it, rest unconformably upon highly inclined metamorphic rocks (Palæozoic)—the plane of unconformity dipping toward the valley bottom. The younger rocks have been cut into a series of strike ridges and ravines parallel to the cliff face and are also crevassed along joint planes at nearly right angles to their bedding.

In several places throughout the valley, the alluvium is slowly creeping riverwards and in the past few decades notable land slides of this material and several small slips have taken place. Gaping crevasses are formed on the upper surfaces of those areas which are slowly creeping towards the river. The landslides of the years 1881 and 1905 were the most destructive to life and property. In October, 1881, a few miles below Ashcroft on the east side of the valley about 150 acres of bench land (probably weighing about 100 million tons) suddenly sank vertically in one movement to a depth at the back edge of over 400 feet and the lower portion of the slide about 2000 feet wide was forced entirely across the river, a distance of 800 feet to 1000 feet; and abutting against the steep bluff on the opposite side, it filled the whole inner gorge of the valley and formed a dam fully 160 feet high, completely stopping the flow of the river for several days, so that men walked dry-shod across the river bed below the dam.[1] As soon as the water rose and formed an outlet it swept away the slide material, and caused a terrific flood in the valley below.

At Spence Bridge a short distance below the town on the west side of the valley, three slides have occurred in almost the same place within recent years, but the most disastrous slide happened the afternoon of August 13, 1905. A large bluff of alluvium at the base of Arthur's Seat broke away suddenly and descended to the river with great velocity, filling the valley bottom from bank to bank. The slide material, as at Ashcroft, formed a dam causing a mighty wave 10 to 15 feet high to sweep up the river against the current, carrying all before it. The river was completely dammed for four or five hours and rose 20 feet in that time before it found an outlet and rapidly cut through the dam. The wave overwhelmed the Rancherie[2] on the flat below the town of Spence Bridge, killing ten Indians and injuring thirteen. Five Indians were buried alive in the slide.[3]

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[1] Stanton, R. B., Minutes of Proceedings of Inst. of Civil Eng., England, CXXXII, 1897-98, part II, pp. 7 and 8.

[2] Indian ranch.

[3] To show the force the wave exerted, it was stated on good authority that a granite and marble headstone was carried fully 200 yards from its original location without throwing it from its upright position. A horse tied to a hitching post at the rancherie had its tie rope broken, and was carried upstream 300 yards. It was finally thrown ashore on the northern bank of the river, where it managed to get its forefeet in the gravel bank and hold on until the waters receded.

A much older landslide composed of older volcanic and sedimentary materials of a reddish brown colour is traversed by the railway a few miles north of Drynock. A deep cirque-like scar on the upland, with steep bounding walls, may be seen a couple of miles back from the railway and marks the source of the material. The slide material forms exceedingly rough ground containing stagnant pools and simulates in many places a glacial moraine with the thickening of earth flow material down valley. It differs, however, from a moraine in the nature of the materials and the abundant open crevasses on its upper surface.

From the above it is evident that since the retreat of the valley glaciers the rivers have been busy cutting down to grade and excavating the valley fill material. The denuded regions of former vigorous glaciation supplied but little waste to the streams. With the reduction in waste supply and only a moderate reduction in volume the streams degraded their earlier aggraded valley and through normal swinging of the river within the valley developed broad terrace lands. A recent post-Glacial uplift[1] has probably invigorated the river and caused it to incise itself more deeply in its present channel.

It is natural in such youthful valleys, where wasting of land goes on rapidly and the corrasive power of streams is great, that land and rock slides should be of common occurrence. The semi-arid nature of the climate further favours their presence. The agent through whose influence the forces of gravity can produce such results is water. The precipitation in the district is of a semi-torrential type as shown by the character of the valley hillsides which are carved into innumerable gullies and ravines which terminate below in many cases at the terrace flats in alluvial fans or aprons. The ground water table is low in the valleys, both on account of the dry climate and the nature of the steep, rocky slopes bordering the alluvial bench lands, which rapidly shed and drain the surface water into the loose and porous fluvio-glacial materials. At the contact of the alluvium and bed-rock, springs may be noted in some places as is well shown in the Thompson canyon at the mouth of Botanie creek. The surface water oozes through the alluvium by means of drought cracks and creep crevasses and in time reaches a boulder clay or clay-silt layer. This layer, when saturated, forms a plastic medium upon which the heavy overlying mass may flow riverwards. The movement takes places as if on lubricated slipping planes. The earth flow forms a glacier-like mass with open crevasses in its lower extension. A small slip may result in great masses suddenly subsiding at the head and forcing the lower alluvium and toe of the slide forward into the river. As a result, the stream is dammed and a lake formed in which the water rises until it reaches an outlet in the dam when the great volume of water may break loose and flood the valley below.

(*b*) *Data Bearing on Drainage Combined with Outline of Drainage History.*

The Thompson river drains practically the whole district and is a rapid stream with an average gradient of 0·18 per cent, or a drop of about 9½ feet per mile. It and its main tributaries are considered to be antecedent streams with courses inherited from previous erosion cycles. The facts upon which this conclusion is based are recorded in the rock records of Mesozoic, Tertiary, and Quaternary time. A brief discussion of the field data, combined with an outline of the drainage history commencing with the more remote, will here be considered. For the full evidence upon which the following history is based the reader is referred to later sections of this report.

The Palæozoic rock record, dimmed by antiquity, shows no direct evidence of continental sedimentation so that it is impossible to locate the site of any old Pa-

[1] Summary Report, Geol. Surv., Can., 1911, p. 109.

læozoic drainage lines. Owing to the lack of pre-Devonian sediments it is thought, however, that this district formed a part of that ancient land area known as 'Cascadia' on palæogeographic maps[1]. During the early Palæozoic 'Cascadia' underwent continued marine and continental erosion and was brought down to a base level before Carboniferous time. The ancient rivers of this continent probably washed out materials into the bordering epicontinental seas. The western portion of 'Cascadia' was submerged in late Palæozoic time by the 'Vancouver sea'[2] and a great thickness of marine sediments and volcanics was heaped up on the downwarped mid-Palæozoic peneplain.

The Mesozoic record of drainage, although very fragmentary, indicates that this district had more relief, then, than during the Palæozoic era. Through Triassic and lower Jurassic time marine conditions of sedimentation with deposition of muds, sands, and calcareous sediments, continued, interrupted often, however, by igneous activity. During the Jurassic revolution which probably culminated in the late Jurassic, the older formations were uplifted high and deformed. The Coast range and Sierra Nevadas were outlined at this time. A coarse conglomerate near the base of the Spence Bridge Volcanic group (Jura-Cretaceous) near Thompson Siding is composed of much granitic material with boulders arranged overlapping one another eastward. The old fluviatile deposit appears from this to have been laid down in a river probably flowing from the Coast range into an interior basin to the east where the sediments were soon entrapped and protected from erosion by younger volcanics. The drainage following Jurassic mountain building was probably very haphazard and disorganized, with many local lake basins and estuaries in which volcanic, dust, arkoses, and conglomerates accumulated. Youthful conditions of erosion and sedimentation in time gave place to quieter conditions. Volcanism had largely ceased, vegetation flourished, and the dominantly argillaceous sediments of the Lower Cretaceous were laid down in probably brackish water arms of the sea. Diastrophic movements took place about the close of the Lower Cretaceous; the whole region was uplifted and subjected to a long continued period of erosion. The drainage became well organized and by the end of the Cretaceous, it is possible that the land was brought down to a peneplain. The present transverse courses of the Thompson and Fraser rivers were probably outlined at this time.

The Cretaceous erosion surface or possibly peneplain was slowly upwarped about the time of the Laramide revolution and the broader orographic features of the Cordillera outlined. The major Cretaceous rivers maintained approximately their courses throughout the slow uplift. The early Tertiary Fraser and Thompson rivers flowed much as they do now and drained the Interior Plateau country. An Eocene delta (Puget group) was built up at the mouth of the Fraser river. Owing to protective lava cappings in the Kamloops district, a fragmentary record of the Oligocene (?) or more probable Eocene Thompson River valley and some of its tributaries has been handed down to the present. South of Savona, a coarse, chiefly river deposit of boulders, coarse gravels, and sands with some lake material (Coldwater group) lying almost horizontal, outcrops beneath the lava hills and appears to occupy a valley eroded in a well-preserved remnant of the Cretaceous erosion surface. What was probably a tributary of the Eocene Thompson flowed west of Copper creek from the north and represented the ancestral Copper creek. The Coldwater group sediments there, chiefly fluviatile, have been severely deformed however, and dip steeply to the northeast-east. Local rhyolitic eruptions took place during the early Tertiary which effected the drainage, and supplied material for the acidic tuff beds of this period.

[1] Schuchert, Charles: Palæogeography of North America, Bull. Geol. Soc. Amer., vol. xx, pp. 464, 469.

[2] Op. cit., p. 447, 463.

Sedimentation of Coldwater time was closed by a crustal disturbance, whose intensity differed greatly in different parts of the district. This probably Oligocene orogeny inaugurated a new cycle of erosion which removed much of the loose, early Tertiary sediments and prepared the way for the more complete erosional work of the late Tertiary. The topographic relief was probably much reduced and lacustrine sedimentation predominated over the fluviatile of the preceding periods.

Many of the old valleys were filled and the drainage changed considerably in some localities owing to the widespread volcanic activity of the Miocene. Crustal warping in later Miocene time which affected mostly the eastern portion of the district inaugurated the late Tertiary erosion cycle during which the planating work of the mid-Tertiary was continued. Before the end of the Pliocene the deformed Miocene volcanics were bevelled and the interior country reduced to late maturity and local peneplanation. At this time some of the more resistant Palæozoic rock formations, chiefly crystalline limestone, remained surmounting the general level of the peneplain. On this erosion plain of Tertiary age, with few exceptions, the drainage was entirely independent of underlying rock structure. The main Thompson and Fraser rivers had then virtually their present courses which, as described, were first defined in the late Mesozoic.

The Pliocene topography in the interior country was coarse-featured or textured with broad low interstream areas; that in the Coast range was finer textured with smaller interstream areas, and with a greater relief.

The Tertiary closed and the Pleistocene period began with a great regional uplift of a differential character. The Pliocene drainage became deeply entrenched below the Tertiary erosion surface and the present valleys were carved out by the streams, leaving, as in the case of Savona mountain, the more resistant synclinal basins of the deformed Miocene volcanics in relief.

Pleistocene glaciation and river work modified the valleys, leaving in many places throughout the district great thicknesses of fluvio-glacial materials. The rivers since the Glacial period have been busy excavating the valley fill into broad terrace steps, indicating different meander periods at different levels in the downcutting process. The course of the river has been diverted slightly in some localities where land slides have temporarily dammed the stream.

In conclusion it may be noted that although the origin of the landscape in the Interior Plateau and Coast range has been traced far back into geological time and its physiographic development briefly outlined as above, the present topographic surface is dominantly post-Pliocene and younger in age. It may further be noted that here in this section of British Columbia the same conditions of long denudation prevailed in the late Tertiary as have already been identified in many regions outside the British Columbia Cordillera where similar upland surfaces were in course of development.[1]

General and Structural Geology.

GENERAL STATEMENT.

The character, structure, origin, and age of the various igneous, sedimentary,

[1] Atwood, W. W.: Jour. Geol., vol. XIX, pp. 449-453, 1911.
Smith, G. O.: U.S. Geol. Surv., Geol. Atlas, U.S., folio 106, 1904.
Cross, W.: Ibid, Mon. XXVII, p. 202, 1896.
Spencer, A. C.: Ibid, Prof. Paper No. 26, p. 12, 1904.
Ball, S. H.: (Spurr, J. E. and Garrey, G. H.) Ibid, No. 63, p. 52, 1908.
Rich, J. L.: Jour. of Geol., vol. XVIII, pp. 601-632, 1910.
For an analytical summary, see:—
Bowman, I.: Physiography of the United States, in Forest Physiography, pp. 342-368, 1911.

and metamorphic rock formations encountered in the survey of this portion of the Kamloops district will here be discussed.

The former classification and correlation of the formations by Dr. G. M. Dawson[1] have been followed in general, with, however, the two following notable exceptions: it has been found necessary to replace the name Lower Volcanic group used for the extensive development of Jura-Cretaceous rock (mapped as Tertiary on the Kamloops map) in the western portion of the section, by the new term *Spence Bridge Volcanic group.* Again it has been thought advisable to include the Lower Volcanic group and Tranquille beds in the vicinity of Kamloops lake, which are undoubtedly post-Eocene in age, with the conformably overlying Upper Volcanic group and call the whole by the new term *Kamloops Volcanic group.*

Table of Formations.

			Approx. thickness in feet.
Quaternary	Recent	Soil and subsoil	
	Pleistocene	Fluvio-glacial deposits	
Tertiary	Lower Miocene	Kamloops Volcanic group basalt, andesite, agglomerate, breccia, and tuff (Tranquille beds).	3,000∓
	Oligocene (?)	Ashcroft rhyolite porphyry	1,000∓
		Coldwater group conglomerate, sandstone, and shale	5,000∓
Mesozoic	Lower Cretaceous	Queen Charlotte Islands formation (?) chiefly shale, conglomerate and sandstone	5,000±
	Jura-Cretaceous	Spence Bridge Volcanic group liparitic and andesitic lava, tuff, arkose, and conglomerate.	5,000±
	Upper Jurassic (?)	Granitic intrusives.	
	Jura-Triassic	Nicola Group greenstone (porphyrites), impure quartzite, argillite, limestone, agglomerate, and tuff.	10,000∓
Palæozoic	Carboniferous	Câche Creek group cherty quartzite, argillite, greenstone, and limestone (Marble Canyon limestone).	9,500±

DESCRIPTION OF FORMATIONS.

Câche Creek Group.

The Palæozoic rocks in the district are very much metamorphosed and form a complex known as the Câche Creek group[2] composed of cherty quartzites, crystalline limestones, argillites, and greenstones. The major portion of this complex is definitely referable through fossil evidence to the Carboniferous period although the basal portions are possibly Devonian.

Distribution and Thickness.—The Câche Creek group is confined in its distribution to a belt between the Thompson and Bonaparte rivers on the east and the Fraser river on the west. In the district under consideration the Câche Creek rocks are met with first about 3 miles up Bonaparte river where they are in contact with the younger Queen Charlotte Islands formation. The contact runs south through the broad dry Cornwall valley and reaches the Thompson river at Basque. The Thompson river follows the contact for several miles (6·2 miles), until Spatsum is reached where the Palæozoic rocks extend across the river as a narrow belt fringing the river and cut off to the east by a broad underlying granite batholith. The

[1] Report on Area of Kamloops Map-sheet; Geol. Surv., Can., Ann. Rept., vol. VII (1894).
[2] Report on Kamloops Map-sheet, Geol. Surv., Can., Ann. Rept. vol. VII, 1894, p. 37B.

Câche Creek formation is overlain at Toketic by the Spence Bridge Volcanic group which extends in a northwestwardly and southeastwardly direction for many miles.

On account of the unfavourable character of the outcrops in the railway section it has proved impossible to ascertain the full thickness. The estimate of Dawson and order of succession (descending order) is as follows:—

	Feet
"(1.) Massive limestones (Marble Canyon limestone) with minor intercalations of volcanic rocks, argillites, and cherty quartzites. At least 1000 feet seen in some single exposures. Total thickness probably at least	3000
(2.) Volcanic materials and limestones, with some argillites, cherty quartzites, etc. Minimum thickness, about	2000
(3.) Cherty quartzites, argillites, volcanic materials, and serpentines, with some limestone. The thickness of these beds, or of a part of them, was roughly estimated in two places as between 4000 and 5000 feet. Minimum total thickness say	4500
Total	9500

Thus the entire volume of the rocks of the Câche Creek formation, as this is now defined, may be assumed to be about 10,000 feet as a minimum while I am inclined to believe that it really exceeds 15,000 feet."

Lithology.—The rocks belonging to the Câche Creek group form a complex made up of both sedimentary and eruptive types all much metamorphosed. The commonest rock members are cherty quartzites and altered tuffs traversed by veinlets of quartz. They are very fine grained and of a dark grey to yellowish grey and greenish grey colour. Associated with the above and of more local occurrence are dark massive meta-argillites and greenstones. The latter represent contemporaneous eruptive materials since metamorphosed. The argillites have been subject to static metamorphism (silica metasomatism) to such an extent that the planes of breakage never coincide with the bedding planes nor have they a slaty cleavage. In many places grey and white largely crystalline limestones or marbles are intimately interfolded with the above rocks.

The pyritic cherts and sheared rhyolites belonging to this group as exposed on Red hill near Basque have been badly oxidized and form prominent red outcrops. Such oxidized outcrops, owing to the semi-arid nature of the climate, are quite common throughout the region. Near Spatsum, gypsum and china-clay may be seen in crumbling outcrops of red, yellow, and white. The highly coloured decomposed materials are almost devoid of vegetation. The metamorphism, both contact and regional, of the rocks has been so intense that microscopic study throws very little light upon their original character. Under the microscope the cherty quartzites appear to be fine-grained dense rocks, made up of quartz, epidote, and iron ore. Pyrite and magnetite are very common. Some of the slides show obscurely angular forms which suggest a pyroclastic origin for the material, thus pointing toward an original tuff.

The greenstones or altered eruptives are massive, dense rocks of a general dark green colour, sometimes porphyritic with small feldspar phenocrysts scattered throughout a very largely chloritized groundmass. Under the microscope the limestone appears wholly crystalline, and shows larger individuals of calcite in a generally finer crystalline aggregate of the same mineral. Lattice structure is quite pronounced. All the crystals are polysynthetically twinned. Some of the larger crystals have been strained and contorted, producing in places an imbricated

structure. One thin section from a railway cut near 89-mile stable on the Cariboo road, where the rock underlay limestone, proved to be of a calcareous arkose.

Structure.—The original structure of the rocks comprising the group has been greatly obscured owing to their massive character and the fact that they have been chloritized and silicified in the zone of cementation to such a degree that their bedding is seldom discernible or cannot be distinguished from the planes of jointing and shearing.

The observed strikes and dips varied a great deal from place to place, the average strike being in a north-northwest and south-southeast direction with dips chiefly to the west. This is the normal Cordilleran trend for formations in the Main Pacific geosynclinal.

Conditions of Deposition.—The rocks belonging to the Câche Creek formation were probably laid down in a Carboniferous sea ('Vancouver Continental sea')[1] slowly transgressing from the northwest upon a low-lying land area ('Cascadia' positive element[2])which probably supported abundant vegetation. In this continental sea, argillaceous, arenaceous, and calcareous sediments were deposited. The limestones represent the off-shore deposits whereas the carbonaceous argillites and sandstones represent the inshore phases.

Marine sedimentation was interrupted at intervals by volcanic activity, which resulted in the accumulation of much volcanic dust and the outpouring of lavas.

Age and Correlation.—Fossils were collected in 1871 by Mr. James Richardson from a locality on the Cariboo wagon road 2½ miles above the 89-mile stable. The following genera were recognized: *Cyrtina*, *Spirifera*, *Rhynchonella*, a small *Myolina* and a *Euomphalus*. Mr. Billings reported them as follows: 'Although none of the above have been determined specifically, they indicate almost certainly a horizon between the base of the Devonian and the summit of the Permian.'[3]

In 1877 the diagnostic Carboniferous fossil *Fusulina* was found in a few localities outside the limits of this district. The Fusulina were found in limestone of the Câche Creek group at Stuart lake (lat. 54° 30'), Dease river (lat. 59° 15'), Frances river (lat. 60° 30'), and on Tagish lake (lat. 60°). A large foraminifera *Loftusia columbiana* has been found and described by Dawson in the Marble Canyon limestone[4]—the upper member of the Câche Creek group. Associated with the above fossils are remnants of crinoids and corals. The lower portion of the Câche Creek group may be older than Carboniferous but as yet no characteristic Devonian fossils have been found.

The Câche Creek group may be correlated with Daly's Attwood series[5] of the 49th parallel belt to the south. The lower portion of the group would correspond to the Knobhill group[6] of Phoenix, and the Franklin group[7] of the Franklin camp; the upper portion to the Brooklyn limestone formation of Phoenix and the Gloucester limestone formation of Franklin, the latter containing *Crinoid* columnals and an obscure *Fusulina* (?).

Nicola Group.

The Nicola group includes a vast thickness of volcanic rocks which are inter-

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[1] Schuchert, Charles, Paleogeography of North America, Geol. Soc. Amer. Bull. vol. xx, pp. 447, 463.

[2] Op. cit., p. 464, 469.

[3] Report of Progress, Geol. Surv., Can., 1871–72, pp. 61–62.

[4] Dawson, Dr. G. M., Quart. Jour. Geol. Soc. 1879, p. 69.

[5] Daly (R. A.): The Geology of the North American Cordillera at the 49th Parallel, Memoir No. 38., Geol. Surv., Can. 1913.

[6] Le Roy (O. E.): The Geology and Ore Deposits of Phoenix, B.C., Memoir No. 21, Geol. Surv. Can., 1912, p. 30.

[7] Drysdale (C. W.): The Geology of the Franklin Mining Camp, B.C. Geol. Surv., Can. In preparation.

stratified with marine sediments. They lie within the same general geosynclinal belt as do the underlying Câche Creek rocks, although separated from them by an unconformity.

Distribution and Thickness.—The Nicola formation has a wide distribution in the railway belt examined and extends with few interruptions from the eastern border of the sheet to Spatsum, a distance of about 40 miles. The thickness of the formation is roughly estimated at between 10,000 and 15,000 feet.

Lithology.—The rocks in the Nicola group are chiefly altered eruptives of both flow and fragmental type with included argillaceous, calcareous, and arenaceous beds. The altered eruptive rocks (porphyrites) have a general greenish colour and are included under the convenient field term of greenstones. They are largely diabasic and basaltic in composition. The argillites are dark grey in colour and massive; the limestones found most extensively near the summit of the series, are light to dark grey and contain many impurities.

A greenish grey rock of the Nicola series collected from the north shore of Kamloops lake proved, under the microscope, to be an amygdaloidal augite porphyrite containing augite, plagioclase, and iron ore in a groundmass of the same minerals. Some orthoclase and quartz are also present. The amygdules are of calcite and prehnite. A dark green, medium-grained rock showing reddish weathered-out olivines outcrops on the Canadian Northern Pacific railway west of Copper creek and elsewhere in this vicinity. It is an augite picrite porphyrite, a rock somewhat similar to the augite porphyrite just described, but containing olivine and more basic in composition. The chief minerals are augite, olivine, iron ore, titanic oxide, serpentine, chlorite, and epidote. The commonest lavas proved to be andesites and the pyroclastics are altered andesitic tuffs and coarse agglomerates.

Structure.—The lavas are very massive and it is difficult to determine the structure of the group. In places, the series appears to have been broadly folded into anticlines and synclines with general Cordilleran trend. There is no general uniformity of structure, however, and local faults are of common occurrence. The upset structure of portions of the group is probably largely due to the deformative movements accompanying the intrusion of the late Jurassic granitic batholith. The Nicola group sediments (chiefly calcareous) in contact with the batholith in the vicinity of Spatsum have been metamorphosed at the contact into cherts or hornstones. The topography in this vicinity closely conforms to geological structure.

The strikes and dips of the master joint planes in the group were observed but no definite system could be recognized. Calcite seams frequently fill the joint planes in the greenstones.

The series is cut in many places by younger aplite dykes which are probably complementary to the underlying granitic batholith. The Nicola group lies unconformably upon the Câche Creek group and is cut off at the top by the Cretaceous surface of erosion. Many cappings of Tertiary rocks are found upon this ancient erosion surface.

A dyke of the rare rock alnöite[1] was found intrusive into the rocks of the Nicola group about 2 miles east of Semlin. The age of the intrusion whether Mesozoic or Tertiary is uncertain, but on account of its intimate association with Nicola rocks, the occurrence will be here described.

This interesting rock type outcrops on a rocky knoll scarped and undercut on its southern flank by the Thompson river. At this point in the valley bottom the meandering river, on encountering the projecting rock shoulder of the Nicola

[1] Adams, F. D.; Am. Jour. Sci., vol. XLIII, 1892, pp. 269–279.
Rosenbusch, H.; 'Mikroskopische Physiographie': 1907, vol. II, p. 705.
Harvie, Robert; Trans. Royal Soc. of Canada, Third Series, 1909–1910: vol. III, sect. IV, pp. 249–299.

group, reached its limit of free swing and was forced to make a sharp bend southward where it continued to deeply incise itself within the loose fluvio-glacial materials that form the valley fill.

The alnöite dyke averages 4 feet in width, strikes northeast and southwest and dips 70° to the southeast. Blocks of alnoite containing large plates of biotite (first generation biotite) up to one inch in diameter in a dark fine-grained groundmass have been taken from the talus and cliffs to help form retaining walls for the wagon road between Walhachin and Ashcroft. It was from this locality that the alnöite-like rock described by Dr. F. D. Adams in Dawson's Kamloops report[1] was very likely obtained. Dawson reported that the rock was probably a dyke of Tertiary age, but that the rocks at the locality were much broken and confused.

Under the microscope, the rock consists of large phenocrysts of biotite, olivine, and augite in a fine-grained groundmass of the same minerals. The augite shows zonal structure and the olivine has largely broken down to serpentine. Perovskite is present in small dusty square outlines and melilite occurs in lath-shaped forms which show obscurely the pegged-in structure. The melilite is partly decomposed to calcite. Magnetite is disseminated in small grains through the groundmass. Feldspar is entirely wanting in the rock.

Origin.—The Nicola rocks are chiefly of volcanic origin, having been thrown out from vents and deposited in the Jura-Triassic sea bottom along with clays, sands, and calcareous sediments.

Age and Correlation.—The age of the Nicola group has been determined to be of Triassic age grading up into lower Jurassic. The scattered joints of a crinoid columnal closely allied to *Pentacrinites asteriscus* were found by Dr. G. M. Dawson in the limestone of McDonald river and Nicola lake. *Pentacrinites asteriscus* has been obtained from Triassic beds in the Pah-Ute range of Nevada[2] and in California localities it is associated with undoubted Triassic fossils.[3]

In 1890, the following fossils were obtained by Dawson from limestones near the mouth of Deadman creek: *Myacites* like *M. humboldtensis*, Gabb., a *Daonella* like *D. lomaneli*, a *Trigonodus*, a *Cardita* and other fragments. In 1894, Dawson made a detailed examination of the rocks on the east side of the Thompson, south of Ashcroft, and found fossils at two different horizons, separated by about 12,000 feet of strata. The lower horizon yielded a *Daonella*, a *Panopea* like *P. remondi*, Gabb. The upper horizon contained two species of *Rhynchonella*, one of *R. gnathophora*, a *Pecten* like *P. acutiplicatus*, Gabb, and *Entolium* like *E. equabilis* Hyatt M.S. and *Lima parva*, Hyatt, M.S. Professor Hyatt believed the upper horizon to be of lower Jurassic age, equivalent to the Hardgrove sandstone, and possibly to the Mormon sandstone of Taylorville, California.[4]

A large number of small lots of fossils were collected during the past field season from several localities in the calcareous members of the Nicola group. The fossils were sent to Dr. T. W. Stanton, of Washington, D. C., for determination, who reports: 'I have not been able to make any satisfactory determination and can only say that the general character of the fossils, with possibly one or two exceptions, indicates that the rocks are Jurassic and it is possible that some, or all of them may be lower Jurassic. I can see no evidence for referring any of them to any of the known American Cretaceous faunas and they show no relationship with the upper Jurassic of the Rocky Mountain region'.

Very large, coarsely-ribbed *Pectens* sp., *Lima* ? sp., and an obscure fragment of an *ammonite* were collected in the vicinity of Rattlesnake hill, northeast of Ash-

[1] Annual Report, Geol. Surv., Can., vol. VII, 1894, p. 388.
[2] U.S. Geol. Exploration of the 40th parallel, vol. IV. p. 280.
[3] Smith, J. P., Bull. Geol. Soc. Am., vol. V, p. 250.
[4] Ann. Rept. Geol. Surv., Can., 1894, p. 112B.

croft. A *Terebratula* sp., large *Pecten* sp. and a fragment of a fibrous shell, possibly *Inoceramus* or a large *Lima* were found in the Nicola group east of Basque. A fragmentary imprint of an *ammonite* came from the Nicola group, on the east lower slope of the Thompson valley, a couple of miles north of Spatsum.

Many fossils were collected from localities in the vicinity of the old 89-mile stable at the mouth of Venables creek where Dawson made collections which were sent to Hyatt for examination.[1] The following fossils were collected: abundant large *Terebratula, Ammonite*? section, *Phynchonella*? sp. Undetermined *pelecypod* and *gastropod* casts, *Pecten* sp. *Pecten* sp. (Entolium?), fragments of *Gervillia* sp. Dr. Stanton reports: 'It is probably Jurassic and may be lower Jurassic as Hyatt thought, but the evidence is not sufficiently definite to be positive about exact correlation.'

The Nicola group may possibly be correlated with the Vancouver volcanics and Sutton formation in Southern Vancouver island[2] and the Cultus formation of the 49th parallel section.[3]

Granitic Intrusives.

Distribution.—The rocks of the Câche Creek and Nicola groups are frequently cut by aplitic dykes and small granitic bosses which are in all probability connected with the Coast Range batholith of late Jurassic or early Cretaceous age.

The granite rocks as indicated on the map are well distributed throughout the area but reach their greatest development in the vicinity of Lytton. They are capped in many places by the younger Tertiary volcanics.

Lithology.—The rocks of upper Jurassic(?) age are light grey to greenish grey, granitoid rocks which vary in composition from true granite to granodiorite and quartz diorite. Hornblende or biotite or both occur as chief ferromagnesian constituents. They are medium-grained rocks consisting of both plagioclase (chiefly andesine) and orthoclase feldspar and quartz with essential hornblende and with accessory biotite, magnetite, pyrite, and titanite. Micrographic intergrowths of the quartz and potash feldspar are present in some of the sections and in these biotite is the chief ferromagnesian constituent. The secondary minerals are biotite, chlorite, epidote, sericite, muscovite, limonite, and kaolin.

A border facies of the granitic batholith east of Spatsum is a granite porphyry containing corroded quartz and phenocrysts of orthoclase and hornblende in a holocrystalline groundmass of the same minerals.

Structure.—The deep-seated rocks have all been subjected to considerable regional metamorphism but in only a few places do they display gneissoid texture. They are greatly jointed and fractured and have also in places pronounced shear zones developed through them.

The granitic rocks, where intrusive into the limestone of the Nicola group, have produced wide contact zones, as is the case in the vicinity of Spatsum, where a wide chert zone fringes the batholith. The uplifting and deformation of the Nicola group at its eastern borders, where in contact with the granodiorite batholith, is probably connected with the intrusion of the latter in late Jurassic time.

Origin.—The formation of the batholith was probably in the nature of a passive invasion preceded by dyke intrusions and possibly volcanic activity, and followed by minor complementary dykes.

Age and Correlation.—The batholith is intrusive into lower Jurassic rocks,

[1] Ann. Rept., Geol. Surv., Can., vol. VII, 1894, p. 115B.

[2] Clapp, C. H.—Southern Vancouver Island: Geol. Surv., Can., Memoir No. 13, 1912, pp. 61–71.

[3] Daly, R. A.—Geology of the North American Cordillera at the 49th parallel. Memoir No. 38, Geol. Surv., Can. 1913.

and is capped by volcanics and sedimentaries of upper Jurassic to Lower Cretaceous age. It may be referred, therefore, to the late Jurassic and correlated with similar batholiths from other parts of the British Columbia Cordillera, as, for example, with a portion of the Coast Range batholith of western British Columbia and Yukon; the Nelson granitic batholith of West Kootenay, Remnel, and Osoyoos batholiths of the Okanagan range and Kruger Mountain plateaus, and the Sumas granite stocks of the Skagit range.[1] In central Washington, it correlates with the Mount Stuart batholith.[2]

Spence Bridge Volcanic Group.

Distribution and Thickness.—The Spence Bridge Volcanic group includes a vast thickness (over 5000 feet) of volcanic materials of both flow and fragmental type. The group is distributed particularly along the eastern front of the Coast range and occupies a synclinorium about 14 miles wide in the railway belt, extending in a northwest and southeast direction. The rocks of the group commence at Toketic and end at Thompson Siding. The Thompson river has in no place cut through to the base of the synclinorium.

Lithology.—The rocks are chiefly andesitic and liparitic lavas with amygdaloidal and vesicular types. The amygdaloids consist of quartz, chalcedony, and zeolites. Interbedded with the lavas are agglomerates, breccias, and tuffs, the latter containing plant remains of Jura-Cretaceous age.

The lower part of the formation is made up of massive breccias, tuffs, and lava flows with one layer of coarse conglomerate outcropping on the Canadian Northern railway opposite Thompson Siding. The conglomerate contains many granitic boulders and pebbles with cherty quartzites, greenstones, and porphyrites. The lavas are andesitic and have augite as the chief ferromagnesian constituent. The augite has broken down to uralite in many of the types. The plagioclase approaches in composition that of labradorite.

Comformably overlying the above rocks are white to pale grey liparitic tuff and lava, the latter in many places showing marked spheroidal structure. The former is in places marked by peculiar fine twisted lamination surfaces. The liparite is in turn intruded and capped by andesitic lavas which are interbedded toward the summit of the series with argillaceous sediments. A conglomerate made up chiefly of subangular pebbles of quartz, quarzite and granitic rocks and an occasional fragment of argillite (the whole embedded in an arkosic matrix) outcrops on a summit between Twaal and Murray creeks. The conglomerate member is associated with greyish tuffs and andesitic lavas belonging to the upper horizons of the group. The lavas have porphyritic varieties containing phenocrysts of plagioclase and augite. The basaltic lavas near the top of the series on the Scarped mountains, weather out spheroidally in onion-like forms. Reddish lavas containing cavity fillings of the hydrous silicate stilbite occur near the summit of the series in the vicinity of Drynock, 6½ miles below Spence Bridge.

Structure.—The members of the group are broadly folded into anticlines and synclines, and in some localities they are much deformed. The rocks have been subjected to more regional metamorphism than those of the Tertiary Volcanic formations and can thus be readily distinguished from them. Calcite seams, which are not common in the Tertiary Volcanics, are abundant in the Mesozoic rocks.

No contact between the Spence Bridge Volcanic group and the Queen Charlotte Islands formation was observed so that their probable conformable relations could not be definitely determined.

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[1] Daly, R. A.—The geology of the North American Cordillera at the 49th parallel. Memoir No. 38. Geol. Surv. Can. 1913.

[2] Smith, G. O.—Mount Stuart Folio U.S. Geol. Surv. No. 106 (1904).

Origin.—The members of the Spence Bridge Volcanic group, as the name would imply, are chiefly of volcanic origin although conglomerate beds are found interstratified with the tuffs and breccias. The andesitic eruptions were probably from numerous fissures from which the lava spread out over a broad, comparatively level basin. The main axis of eruption was along the line of the present Arthur's Seat, Mount Murray, and Cairn mountain. The liparitic eruptions were probably explosive in their nature as indicated by the acidic tuffs and breccias. The earlier lavas as they poured westward became intermixed with delta and river deposits from the Coast range. Some of the rivers then flowed through to lake basins nearer the centres of eruption. Around such lakes vegetation was abundant. In this belt, volcanic activity was very pronounced and the outpouring of lavas prevented the accumulation of great thicknesses of coal-bearing sediments as was in progress farther north in the Groundhog district and elsewhere along the eastern front of the Coast range.

Age and Correlation.—Plant remains were found in the tuff beds of the Spence Bridge Volcanic group in the Thompson valley, at an elevation of 2500 feet above sea-level. The beds outcropped on the western slope of the Pimainus hills about half way between the Nicola river and Pimainus creek. The plants were examined by Mr. W. J. Wilson, who reports as follows: 'This small collection, though fragmentary and poorly preserved, seems to indicate that the rocks in which it was found are of Lower Cretaceous age, probably about the equivalent of the Kootenay, Potomac or Wealden. Some of the plants, however, have a decidedly Jurassic aspect.'

This collection was then forwarded to Dr. F. H. Knowlton, of Washington, who confirmed most of Mr. Wilson's determinations. The corrected list is as follows: *Nilssonia* cf *Schaumburgensis* (Dunker), *Taeniopteris* cf *T. orovillensis* (Font), *Sequoia reichenbachii* Heer, *Podozamites lanceolatus* (L. and H.), *Podozamites* cf. *P. gramniæfolia*, *Podozamites fragments*, *Sagenopteris* cf. *S. paucifolia* (Phili) Ward, *Cladophlebis* cf. *C. falcata montanensis* Font, *Cladophlebis* cf. *browniana* (Dunker) *Oleandra*, *Equisetum?*, *Sphenolepidium* sp., fragments of bark and stems. Referring to this collection, Dr. F. H. Knowlton writes[1]. 'They are certainly lowest Cretaceous, if not indeed upper Jurassic. So far as I recall *Sagenopteris* has not been noted in the Kootenay, and the several species of *Nilssonia*, *Tæniopteris*, etc., which seem to compare most closely with them are Jurassic species. . . On the whole, I expect it is best to regard them as Kootenay—with decided Jurassic affinities. They have, of course, absolutely no relation to the Miocene'.

This new plant evidence favours Dawson's early views regarding the age of the volcanic rocks of this group which he thought, in 1877, were connected with the contiguous Cretaceous strata underlying the Fraser River Lower Cretaceous.[2] He correlated them on lithological grounds with certain 'porphyrites' which had been found to contain earlier Cretaceous fossils in the more northern parts of British Columbia in 1875 and 1876.[3] Dawson later preferred to consider them as of Tertiary age on account of their intimate association with distinctly Tertiary volcanic rocks and classed them in his Lower Volcanic group of Miocene age.[4]

The Spence Bridge Volcanic group very probably correlates with the Hazelton group (at least 5000 feet thick) farther north in the Skeena River region. Concerning the Hazelton group Mr. W. W. Leach writes: 'Generally speaking, it may be said that to the south, this formation is built up almost entirely of flow rocks, chiefly andesites, massive, with characteristic dark red and green colours. At the top of the series, a few thin beds of fossiliferous sandstones and shales appear, a

[1] Personal communication.
[2] Ann. Report, Geol. Surv., Can., 1894, vol. VII, p. 151B.
[3] Report of Progress, Geol. Surv., Can., 1877–78, p. 111B.
[4] Dawson, G. M.—Geol. Surv., Can., Annual Report, 1894, vol. VII. p. 199B.

number of fossils from which have been determined to be of Jurassic or early Cretaceous age. These are overlain directly by the coal-bearing Skeena series, so that in the Telkwa River district little difficulty was encountered in separating these two formations in the field. On travelling northwards, however, it was found that these flows gradually thinned out, and were replaced by a considerable thickness of tuffs and tufaceous sandstone, although a few of the andesite beds extended as far north as Hazelton. Locally these tufaceous beds are known as sandstone, and where altered near the contact with intrusive masses, as quartzite.[1]

The Spence Bridge Volcanic group may be further correlated on lithological grounds with Daly's Skagit Volcanic formation (5200 feet thick) and Pasayten Volcanic formation of the Western Geosynclinal Belt at the 49th Parallel[2] both of which contain augite andesites. The Skagit formation contains both liparitic and andesitic lava flows having similar relationships to conglomerate beds, as have the Spence Bridge Volcanics. The Naknek formation[3] of Cooke inlet, Alaska peninsula, which also consists of conglomerate, arkose, sandstone, and shale with (interstratified) andesitic flows (with a total thickness of about 5000 feet), may also be correlated with the above.

Queen Charlotte Islands Formation(?).

Distribution and Thickness.—The shales, sandstones, and conglomerates included under this formation, occur in two isolated areas, the main one in the vicinity of Ashcroft occupying an area of about 48 square miles, and the other at the mouth of Botanie creek of about 2 square miles in area. This formation has been referred by Dawson on lithological grounds to the Lower Cretaceous and correlated with the Queen Charlotte Islands formation of the Pacific coast.

The approximate thickness of the Ashcroft Queen Charlotte formation is about 5000 feet. The Botanie Creek Queen Charlotte formation is too severely metamorphosed and drift covered to give any idea of its thickness.

Lithology.—The rocks belonging to this sedimentary series vary from coarse conglomerates to fine-grained argillites and shales. Much of the material is of an arkosic character and the sandstones are feldspathic rather than siliceous. The shales and argillites which occur in the upper part of the section are dark and in many places carbonaceous. The sandstones are, as a rule, highly indurated and of a greenish or greenish grey to grey colour.

The conglomerates are never in great thickness and are made up of fragments of greenstones, cherty quartzites, and granitic rocks generally in an arkosic matrix. The fragments are often well rounded, but in some beds are angular and subangular and, in the latter case, the beds are found near the borders of the area and probably represent subaerial cone or fan deposition at the borders of the basin. In the Botanie Creek area the blackish and brownish shales have been badly metamorphosed and slickensided.

Structure.—The rocks belonging to the Queen Charlotte formation of Ashcroft and Botanie Creek localities, have all been considerably deformed and their original structure is very obscure. The least deformation is shown at the eastern border of the Ashcroft area where the dips are comparatively low, ranging from 10° to 45° west. The formational dips steepen westward to 60° and up to vertical. Broadly speaking, the formations strike in a northerly and southerly direction, forming a syncline with its western limb overturned, faulted, and, in places, crushed. Within the main synclinal and particularly in the western portion of it, are

[1] Summary Rept. Geol. Surv., Can., 1910, p. 93.

[2] Daly, R. A.—The Geology of the North American Cordillera at the 49th parallel, Geol. Surv. Can. Memoir No. 38. 1913. pp. 475–529.

[3] Stanton and Martin, Bull. Geol. Soc. of Am., vol. XVI (1905), p. 410.

numerous minor folds and local faults. The formational strikes in the southern portion of the inlier are approximately east and west, and the deformed beds form a local syncline within the main one, but with an east and west trend.

Origin.—The rocks are all of sedimentary origin and were probably deposited after the late Jurassic mountain-making revolution, by streams draining into marine estuaries or brackish water lakes in which Selachian[1] fish and such organisms as Pectens and Goniobasis lived. At the borders of the basin or estuary, subaerial deposition was in progress, and coarse conglomerates with, here and there, quite angular fragments accumulated. Arkosic materials were swept down by the rivers; vegetation flourished and carbonaceous muds accumulated in the central parts of the basins.

Age and Correlation.—Fossils are scarce in this formation and were found last field season for the first time in the Ashcroft area. Very large coarsely ribbed pectens and undeterminable forms were found on the west flank of Rattlesnake hill, a few miles north of Ashcroft. Concerning the pecten, Dr. T. W. Stanton writes:[2] 'So far as the characters are preserved this specimen might be Jurassic, Cretaceous or Tertiary, but it is probably from the Jurassic.'

Dr. G. M. Dawson, in 1893, found some small fragmentary fish bones in the Botanie Creek shales associated with what were apparently the crushed tests of minute Ostracoda.[3]

The Ashcroft and Botanie Creek areas of the Queen Charlotte formation Dawson correlated lithologically with the Fraser River Cretaceous. Plant remains were collected by him in the Fraser River Cretaceous on the east side of the Fraser, about a mile above the mouth of Stein creek. Sir J. W. Dawson has described the collection made in 1877 as containing two indeterminable dicotyledonous leaves and one flabellate leaf resembling that of a Salisburya.[4] Concerning the collection made in 1890, he supplies the following note:—

> '1.—*Platanus obtusiloba*, Lesq., or closely allied. This is a species found in the Dakota group in Nebraska.
>
> '2.—Probably *Magnolia tenuifolia*, Lesq., which is found in the Dakota of Nebraska and also in the Dunvegan group of Peace river.
>
> '3.—*Menispermites*, allied to *M. grandis* of the Dakota group, but probably specifically different.
>
> '4.—*Laurophyllum*. Several leaves referable to this genus, and near the Dakota species.
>
> '5.—*Sequoia*, a fragment which may be S. Rechenbachii.
>
> '6.—Grass-like stem or *Phragmites*, *Carpolites*, etc.,—scarcely determinable. The whole probably belongs approximately to the age of the Dakota group or near to this.'[5]

No contact between the Queen Charlotte formation and the Spence Bridge Volcanic group was present in the area mapped, so their exact relations could not be ascertained. It is thought, however, that Dawson's first views were correct with regard to the relations of the two, and that the Spence Bridge Volcanic group (Jura-Cretaceous) is older and underlies conformably the Queen Charlotte formation. If this be the case the Queen Charlotte formation of this district would probably correlate with the Skeena series (coal-bearing) farther north which also consists of carbonaceous shales and sandstones.

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[1] Ann. Report, Geol. Surv. Can., vol. VII, 1894, p. 148 B.
[2] Personal communication.
[3] Annual Report, vol. VII, Geol. Surv., Can., 1894, p. 154B.
[4] Report of Progress, Geol. Surv., Can., 1877–78, p. 110B.
[5] Annual Report, 1894, Geol. Surv., Can., vol. VII, p. 148B.

Coldwater Group.

Distribution and Thickness.—The sediments of early Tertiary age are known as the Coldwater group and have a relatively small distribution within the limits of the map. They extend in two detached areas, one on the north side of Kamloops lake elongated in a northerly direction and capped by the younger volcanics to the east and west, and the other belt on the south side of the lake fringing the lower Miocene volcanics of Savona mountain. They represent the remnants of former much more extensive beds of continental origin preserved through time by protective lava cappings.

Lithology.—The Coldwater group is made up of coarse conglomerates, shales, and sandstones all of continental type. The conglomerates are dark brown or greenish grey in colour and are composed of well rounded to subangular boulders chiefly of metamorphic (including cherty quartzites, greenstones, etc.), sedimentary, and igneous rocks varying in size from a few inches to 2 feet and more in diameter, the whole embedded in a firm compact cement. They include fragments of practically all the older formations and none of the Miocene volcanics were found contained in them. The conglomerate shows a rude stratification in places and the flatter boulders parallel one another and overlap in the direction of the flow of the early Tertiary stream that deposited them. Interbedded with the conglomerates are greyish feldspathic sandstones and tufaceous shales.

The Tertiary clastics are not so well indurated as the Cretaceous and joint planes do not traverse indiscriminately boulders and matrix alike as they do in the case of the Mesozoic conglomerates.

Structure.—The Coldwater group rocks of the southern area underlying the volcanics (lower Miocene) of Savona mountain, lie with very low dips to the south and although uplifted they have apparently not taken part in the deformative movements that elsewhere effected beds of this age prior to Miocene volcanism. The rocks appear to fill erosion channels in a Mesozoic (Cretaceous) erosion surface.

The conglomerates and sandstones of the group belonging to the northern area west of Copper creek, have been badly deformed along a north-northwest and south-southeast line and dip steeply to the northeast-east. In places, the beds even stand vertical. The sediments are made up chiefly of well water-worn cherty quartzites from the Câche Creek group and of greenstones and altered granitic rocks.

Conditions of Deposition.—The sediments appear to have been laid down by swift-flowing rivers in valleys and local lake basins. The topographic relief as indicated by the coarseness and unconcentrated character of some of the sediments must have been considerable. The coarse heterogeneous sediments which show slight stratification and contain subangular to angular boulders probably represent alluvial cone or fan deposition. The well-stratified and water-worn boulder conglomerate represents river deposition. The fine-grained sandstones and shales were laid down in quiet waters and are chiefly of lake origin. Considerable tufaceous material of acidic nature is found in the fine-grained sandstones and shales, which indicates that volcanic activity was in progress at the time.

It is thought that the climate then was probably humid and cool, as indicated by the light coloured leached sediments and grey and greenish grey colours with the presence of carbonaceous shales containing plant remains.[1] Under such conditions of climate and relief continental erosion must have proceeded rapidly, and great thicknesses of loose unconsolidated sediments were laid down in local lake basins and river valleys.

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[1] Barrell, J.—Climate and Terrestrial Deposits: Studies for Students, Jour. of Geol., vol. xvi, pp. 293, 294 (1908).

The deformative movements, however, in the Oligocene (possibly the post-Kenai revolution of Alaska) inaugurated a new erosion interval which removed most of this early Tertiary material before the widespread outpouring of Miocene lavas and pyroclastics. What remnants of Coldwater group sediments and correlated formations that do exist to-day owe their preservation largely to protective lava cappings of Miocene age.

Age and Correlation.—No new plant evidence was obtained in this area from the sediments of the Coldwater group. They are correlated lithologically and structurally with the Similkameen beds[1] (Oligocene?) and the Kettle River formation[2] (Oligocene?) of other portions of the British Columbia Cordillera which are considered to belong to a period between the late Cretaceous and the early Miocene.

The Coldwater group in this district may possibly be correlated with the Kenai series in southeastern Alaska, which consists of friable sandstone, conglomerate, shale, and coal seams similarly deformed and separated from the younger volcanics by an erosion surface. The writer follows Dawson in placing the Coldwater group of this district in the Oligocene(?) but favours an Eocene age for the same and he would refer the post-Coldwater elevation, deformation, and erosion to the Oligocene.

Ashcroft Rhyolite-Porphyry Formation.

Distribution and Thickness.—The Ashcroft rhyolite porphyry formation has only a small development in the district. It occupies a couple of square miles on a prominent hill in the Thompson valley, southeast of the town of Ashcroft and to the west of Barnes lake. It has a maximum thickness approaching 1000 feet and caps unconformably shales and sandstones belonging to the Queen Charlotte formation.

Lithology.—The rock is a rhyolite porphyry varying from coarse to fine in texture and showing in places a fluidal structure. It is a light greenish grey holocrystalline rock of porphyritic habit with mica as the chief ferromagnesian constituent and small limpid quartzes and feldspars as phenocrysts. Under the microscope it was found to consist of: apatite, zircon, iron ore (pyrite, magnetite), titanite, biotite, plagioclase, orthoclase, quartz, chlorite, and kaolin. The structure is porphyritic with phenocrysts of corroded quartz zoned plagioclase, partly kaolinized orthoclase and biotite in a micro-granitic groundmass of the same minerals. The magnetite is included chiefly in the biotite. Apatite is present in small needles and prismoids.

Structure.—The Ashcroft rhyolite porphyry has a massive jointing in planes parallel to the general slope of the hill, which resemble planes of bedding. The formation lies unconformably upon deformed shales and sandstones of the Queen Charlotte formation and is capped unconformably by basalts of lower Miocene age. The rhyolite porphyry was subjected no doubt to the same deformative movements that disturbed the Coldwater group as well as to the erosion cycle prior to Miocene volcanism.

Origin.—It is thought that the rhyolite-porphyry remnant represents the basal portion of an early Tertiary acidic flow of lava which poured out from a local vent. The massive flow being viscous did not extend far from its orifice which is repre-

[1] Camsell, Chas.—Prelim. Report, on a part of the Similkameen District, B.C., Geol. Surv. Can., 1907, p. 27.
Dawson, J. W.—Proc. and Trans. Royal Soc., Canada, vol. 8, sec. 4, 1890, pp. 75–91.

[2] Daly, R. A.—The Geology of the North American Cordillera at the 49th parallel, Geol. Surv., Can. Memoir 38. 1913.
LeRoy, O. E.—The Geology and Ore Deposits of Phœnix, B.C., Geol. Surv., Can. Memoir No. 21, p. 42.

sented possibly by the hill itself. The tufaceous material in the Coldwater group probably represents the products of the same rhyolitic eruptivity only in its earlier stages before the lava itself was poured out. The outpouring of rhyolitic lavas at this time appears to have been confined mainly to local basins or their margins, and not along the axes of the main mountain ranges.

Age and Correlation.—The rhyolite porphyry is thought to have been poured out toward the close of the Coldwater period, and is possibly connected with the pre-Miocene deformative movements. The formation may be correlated with the rhyolite porphyry of the Franklin mining camp[1] which is of early Tertiary age.

Rhyolite flows are also found in the John Day basin, Oregon, intercalated with upper Oligocene tuff and conglomerate beds which bear unconformable relations to the underlying Chico Cretaceous and the capping lower Miocene basalts.[2]

Kamloops Volcanic Group.

Distribution and Thickness.—The rocks belonging to the Kamloops Volcanic group have a widespread distribution throughout the district. They occupy the present hill tops and cap unconformably nearly all the older formations.

The following section in descending order is taken from Savona mountain and gives an approximate thickness of the group.—

Coarse agglomerate (andesitic matrix)	200 feet.
Reddish, black and greenish black lavas, chiefly vesicular and amygdaloidal (contain agate, serpentine, and a little asbestos)	900 feet.
Agglomerates, and ropy lavas	800 feet.
Grey, black, and red basaltic lavas, some vesicular, in places slightly agglomeratic	600 feet.
Total	2500 feet.

Lithology.—The extrusives of the Kamloops Volcanic group are fresh and unaltered in appearance and on this account can readily be distinguished from the Mesozoic volcanic groups. They are mainly basaltic lavas and pyroclastics with younger mica andesites cutting them and forming coarse agglomerates in an andesitic matrix. The latter are the uppermost beds in the series and are well exposed on the summit of Savona mountain.

The basalt in some localities is very basic, and one slide taken from a flat-topped lava hill or mesa near the mouth of Bonaparte creek had over 50 per cent of magnetite in it. This basalt shows pronounced ball and socket jointing. The compact basalt, generally displaying columnar jointing, passes transitionally into vesicular and amygdaloidal types. The amygdules are in many places agates well banded but pale-coloured. Zeolites, green chloritic material, rose quartz, and calcite (the latter intergrown with chalcedony) also fill vesicles. The amygdules are generally oval shaped, due probably to flowage at the time of extrusion, which drew out and extended the gas pores in which the chalcedony and calcite were subsequently deposited.

In some sections of the basalt, the lath-shaped crystals of plagioclase appear under the microscope to have a fluidal arrangement around larger augite individuals. The andesite of Savona mountain and elsewhere is a mica andesite of a pale greyish colour. It is fine-grained rock in which occur numerous porphyritic crystals of quartz, plagioclase, biotite, and augite in a groundmass composed of

[1] Geology of the Franklin Mining Camp, B.C., Geol. Surv., Can. Memoir. In preparation.
[2] Bull. Geol. Soc. of Am., vol. XXIII, No. 2, 1912, p. 246.

a felted mass of the same minerals, with trachytoid structure. Andesitic tuffs and breccias of the same period of eruptivity outcrop on the summits west of Savona mountain.

Structure.—The volcanic rocks of the group east of Ashcroft were broadly folded into synclinal basins and anticlinal domes. Rarely, however, do the formational dips exceed 15°, and west of Ashcroft the members of the group lie almost horizontal. In this respect the Kamloops Volcanic group stands in bold contrast to the unconformably underlying Coldwater group which is in many places much deformed. The group caps the early Tertiary and older formations, and is cut off at the top by the late Tertiary erosion surface, which truncates the folded volcanics. The anticlinal portions have been eroded away leaving the synclinals now exposed on the hill tops.

Origin.—The Kamloops Volcanic group consists mainly of surface lava flows, tuff beds, and agglomeratic accumulations. Many of the dykes in the region probably represent the fissures through which the basaltic and andesitic lavas reached the surface.

The youngest flows of andesite were of more local occurrence and not so widespread in distribution as the basalt flows. Erosion has removed much of this younger material particularly the agglomerate, breccia, and tuff members. The latter represent the volcanic ash and dust accumulated in local lake basins during quiescent intervals.

Age and Correlation.—The rocks of the Kamloops Volcanic group are the most recently consolidated in the district. Plant and fish remains have been found near the base of the series in the Tranquille beds. The plant remains were determined by Dr. D. P. Penhallow who identified the following: *Alnus carpinoides*, *Audromeda delicatula*, *Betula* sp., *B. heterodonta*, *B. macrophylla*, *Carpinus grandis*, *Carpolithes* sp., *C. dentatus*, *Carya antiquorum*, *Cinnamomum affine*, *Corylus americana*, *Cratægus tranquillensis*, *Cyperites* sp., *Ficus asiminaefolia*, *Gingko adiantoides*, *Glyptostrobus europœus*, *Juglans rhamnoides*, *Picea tranquillensis*, *Pinus* sp., *P. trunculus*, *Planera longifolia*, *Populus acerifolia*, *Populus cuneata*, *P. mutabilis oblonga*, *P. zaddachi*, *Rhamnus eridani*, *Salix varians*, *Sequoia* sp., *S. angustifolia*, *S. brevifolia*, *S. heerii*, *S. langsdorfii*, *Taxodium distichum miocenium*, *T. orcidentale*, *Typha latissima*, *Ulmus tenuinervis*, *Viburnum dentoni*. Dr. Penhallow concludes that: 'An inspection of the distribution shown in the above table[1] conveys the information that there are

Eocene, chiefly lignite Tertiary	14
Oligocene,—	
Upper Eocene	14
Lower Miocene	4
Miocene	15

thus giving a preponderance of the Eocene over the Miocene, in the proportion of 28 to 19; but inasmuch as the Eocene and the Miocene are practically equal, while there are 18 Oligocene, the conclusion appears justified, to the effect that these beds [Tranquille beds near base of series] are of Oligocene age, and possibly not higher than upper Eocene, though the presence of such strong Miocene types as *Ficus asiminæfolia*, *Pinus trunculus*, and *Sequoia brevifolia* would seem to give them a stronger Miocene tendency. I therefore assign them to the Lower Miocene provisionally.' The flora of the lower portion of the Kamloops Volcanic group was apparently transitional with stronger affinities toward the Miocene. Fossil fish were collected the past season by B. Rose from Red point on Kamloops lake and await determination.

[1] Report on Tertiary Plants of British Columbia: Geol. Surv., Can. (1908), No. 1013, pp. 115–116.

The Kamloops Volcanic group, including the Tranquille tuff beds at their base, are certainly younger than the deformative and erosional periods which followed the deposition of the Coldwater group rocks (Oligocene?) The post-Coldwater deformative movements may be correlated with those general crustal movements throughout the Cordillera known as the post-Kenai revolution in Alaska. Brooks[1] in Alaska has considerable evidence to show that this dynamic revolution occurred there during late Eocene or early Miocene time.

It seems safe to refer the Kamloops Volcanic group to the lower Miocene and correlate it with other extensive basaltic and andesitic flows bearing similar structural relations to early Tertiary and older formations in the Boundary district, and elsewhere throughout the Cordillera.

The placing of this group in the Miocene following Oligocene elevation and deformation would be in accord with Ralph Arnold's conclusions regarding the Tertiary on the Pacific coast[2]. He concludes that, 'the periods of marked elevation were the Oligocene, late Pliocene, and Quaternary; the periods of maximum subsidence were the middle Eocene and upper Miocene; the periods of greatest volcanic activity were the middle Eocene and the middle Miocene.'

Superficial Deposits.

Fluvio-Glacial Deposits.—Boulder clay or glacial till blankets many portions of the upland surfaces. It consists of a hard sandy clay, with stones and boulders scattered abundantly and irregularly through it. Glacial erratics are also commonly found on the upland tracts. The valley-fill material flooring the deeply entrenched valleys is largely composed of unmodified and modified morainic debris. The modified glacial materials predominate over the true till sheets and were probably laid down by heavily burdened streams as outwash valley-trains contemporaneous with the retreat of the valley glaciers. Such deposits are well stratified and consist of cross-bedded sands, silts, and gravels. A stratified clay silt occurs at a uniform level throughout the region, and was probably deposited under quiet lake conditions following the first period of valley glaciation.

The structure, mode of origin, and correlation of the Pleistocene deposits are discussed under the physiography and glacialogy section of this report and will not be repeated here.

Stream Deposits.—The recent deposits consist of the present stream deposits such as sands, gravels, silts, and soils.

Economic Geology.

The chief minerals of economic value in the district both metallic and non-metallic may be enumerated as follows: placer gold, mercury, copper, coal, clay, lime, agate, and chalcedony.

PLACER GOLD.

Dr. G. M. Dawson, who made a detailed study of the placer deposits, gives the following list of conglomerates and gravels in the Kamloops district either known to be auriferous or that may be regarded as possible sources of gold:—

'1. Cretaceous Conglomerates.—No gold yet found.

'2. Oligocene Tertiary Conglomerates.—Traces of gold found.

'3. Miocene Conglomerates or buried river gravels.—Not yet discov-

[1] Brooks, A. H.—Prof. Paper No. 45, U. S. Geol. Surv., 1906, pp. 292–293.

[2] Arnold, Ralph.—Environment of the Tertiary Faunas of the Pacific coast of the United States; Jour. of Geol., vol. XVII, 1909, pp. 509–533.

ered in this district, though sandstones and water-bedded tufaceous rocks are known in some places.

'4. Early Pliocene gravels—

'(a) In high-level valleys.—Buried under drift deposits wherever remaining; not prospected.

'(b) Along main river valleys.—Excavated and redistributed in succeeding period.

'5. Later Pliocene gravels.—Possibly in part still remaining along Fraser, Thompson, and other deep valleys, and if so, probably in some places above, in others below the present river-level. These would undoubtedly be richly auriferous, but no such deposits appear yet to have been discovered or worked by miners.

'6. Boulder clay.—In this the gold is probably everywhere too much disseminated for profitable working.

'7. Interglacial gravels, silts, etc.—These have constituted most of the drift-filling of the Fraser and Thompson at one period, and still form the mass of the river terrace—probably containing payable gold in places.

'8. Gravels and bouldery deposits capping river terraces.—These, with the gravels of the next class, have been those chiefly worked on the Fraser and Thompson. Nearly everywhere auriferous along these rivers, and often elsewhere.

'9. Modern river gravels.—Nearly everywhere auriferous along the Fraser, frequently so on the Thompson, and often elsewhere.'[1]

In discussing favourable places for prospecting, Dawson states: ' . . . . . wherever the early Pliocene valleys have been excavated on or near to areas of the older rocks, and particularly those of the Câche Creek formation, placer deposits of gold referable to the time of erosion of these valleys may be looked for. It must be borne in mind, however, that these valleys lay open to the work of the ice of the glacial period, and that it is probably in the main, if not alone, in such of them as lie transverse to the general direction of motion of this ice, that placer deposits may be expected still to remain intact. Where the direction of the old and wide valley nearly coincided with that of the motion of the Cordilleran glacier, it is probable that in most cases the original deposits may have been swept out to the bottom by this agent.'[2]

MERCURY.[3]

In the vicinity of Copper creek, Kamloops lake, occur deposits of cinnabar which have not been worked since 1897. The cinnabar occurs in irregular veins traversing a grey feldspathic and dolomitic rock which readily weathers to a yellowish colour. The country rock is an altered greenstone containing pyroxene and olivine. The cinnabar is associated with small quantities of stibnite and has a calcite and quartz gangue. The mines have produced over 7,000 pounds of mercury. It is said that 150 tons of ore produced 114 flasks of mercury valued at £900.

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[1] Report on Kamloops Map sheet, Annual Report, vol. VII (1894), pp. 328–329B.

[2] *et. seq.* p. 319B.

[3] Report on Kamloops Map Sheet, Annual Report, vol. VII, Geol. Surv., Can., 1894, pp. 340–341B.

Report of Minister of Mines, B.C., 1896, pp. 568–571; 1897, p. 614.

Mining Districts near Kamloops Lake, B.C., by G. F. Monckton., Trans. Inst. Mining Engineers, Sheffield, England, 1899.

COPPER.

Copper ore (chalcopyrite and bornite) also occurs in the vicinity of Copper creek in small quantities and appears to be associated with dykes of augite porphyrite.

COAL.

Lignite has been described from many localities in the Tertiary sedimentaries but no workable seams have as yet been discovered within the limits of the district examined. A small bed of lignite outcrops at Red point, Kamloops lake, and was first found during the progress of the Government railway surveys in 1878.

No workable coal seams have as yet been found in the Jura-Cretaceous (Spence Bridge group) or Lower Cretaceous(?) (Queen Charlotte Islands formation) of this district, although coal seams do occur in formations of the same age farther north in the Skeena and Groundhog districts.

CLAY.

The clay silt formation ('White silts') partially filling the youthful valleys affords an unlimited supply of material from which ordinary bricks of fair quality might be made.

The clay deposits here resemble those now being worked 2½ miles west of the town of Kamloops where 'dry wood is used for fuel, at a cost of $3.50 per cord, and a half cord of wood is consumed in burning 1,000 bricks.'

'The bricks are burned hard and to a deep red colour, the price obtained is $14 per thousand at the yard, or $16 delivered at Kamloops, where the output is mostly used.'[1]

LIME.

Limestones (Marble Canyon formation) suitable for burning and the production of lime are very abundant and are indicated on the map.

AGATES AND CHALCEDONY.

Agates and chalcedony occur in considerable abundance as cavity fillings (amygdules) particularly in the younger Tertiary lavas. The colours are usually pale but many prettily banded and striped specimens may be obtained from the amygdaloidal lavas of the Kamloops Volcanic group.

Geological History.

A brief outline of the succession of the ascertained geological events in this portion of Canada, including the most important facts and suggestions concerning the structure, stratigraphy, and correlation of the formations examined will here be given. The facts must necessarily be interwoven with theory in such a section in order to give the reader as connected and realistic a version as possible of the life history of the region.

The Palæozoic period, so far as it may be inferred from rock records of that age, was a time of ever-changing epicontinental seas with intervening land barriers of a general low topographic relief.

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[1] Preliminary Report on the Clay and Shale deposits of the Western Provinces, Geol. Surv. Can., Memoir No. 24–E (1912), pp. 122, 123.

There is no record in the Kamloops district of pre-Carboniferous history and it is thought that the district then formed a part of an ancient land barrier known as 'Cascadia' in paleogeography.[1] This probably almost featureless land area underwent long continued erosion and supplied sediments to the bordering early Palæozoic seas including the Rocky Mountain basin to the east and the Yukon and Alaska basins to the north. Erosion progressed until the land surface was at length brought down to a plain of very low relief.

This mid-Palæozoic peneplain slowly subsided beneath a transgressing embayment of the Pacific ocean from the north (Vancouver continental sea[2]) in which over 9,000 feet of marine sediments and intercalated volcanics became deposited before the close of the Palæozoic period represented by the Câche Creek group. The oceanic waters then were probably warm, as suggested by the presence of fossil crinoids, corals, and foraminifera. Although the sea no doubt engulfed low-lying swamps containing much vegetable material, conditions were not favourable for the accumulation of coal seams. Sedimentation proceeded on a sinking sea floor, consisting first of argillaceous material followed by cherty and calcareous material (Marble Canyon limestone), the latter indicative of an expanding sea, which may have covered the whole region. Sedimentation was interrupted at times by the intrusion and extrusion of lava and the accumulation of tuff beds partly on the land and partly in the sea.

The Palæozoic period closed with an uplift of the sea bottom and bordering Carboniferous coastal plain. Although this was accompanied by deformation in the interior of British Columbia (marked by an angular unconformity between the Carboniferous formations and those of the overlying Triassic) some coastal regions, as evinced by conformities, underwent continued sedimentation into the Mesozoic period. Diastrophism in the west at this time was not so pronounced as that going on—the Appalachian revolution—in the east. It was sufficient, however, to raise the continent as high as it probably was at the beginning of the Palæozoic era.

The Mesozoic and later history is characterized by a higher relief of the continent with a stronger tendency towards emergencies rather than submergencies as was so typical of Palæozoic history.

The Mesozoic period opened with vigorous erosion of the newly uplifted land surface which probably had a moderate relief. Erosion was followed by another marine transgression by an embayment of the Pacific ocean and over 10,000 feet of sediments and predominantly volcanics (Nicola group) were laid down in this Jura-Triassic sea bottom. As sedimentation proceeded the proportion of clastic materials gradually decreased and the deposits became more calcareous (lower Jurassic) indicative of continued subsidence and retrogression of shore-lines. Vulcanism almost ceased and a through connexion eastward with the Jurassic Logan sea may have existed. The climate as suggested by the animal life (corals, etc.) may have been subtropical.

In the late Jurassic, a great mountain-making uplift took place accompanied by large intrusions of igneous rock (granitic intrusives). The Nicola group limestones in the vicinity of Spatsum were probably then uptilted. This orogenic movement is known as the 'Jurassic revolution' and it gave birth to the Coast ranges, Sierra Nevadas, and other rugged ranges in the western Cordillera.

About this time (Jura-Cretaceous) volcanic eruptions on a large scale broke forth from fissures and central craters, and resulted in the accumulation of over 5000 feet of andesitic and liparitic lavas with corresponding pyroclastics as well as contemporaneous conglomerates and arkoses (Spence Bridge Volcanic group).

[1] Schuchert, Charles, Palæogeography of North America, Bull. Geol. Soc. Am., vol. xx, pp. 427–606.

[2] *et. seq.*, pp. 447, 448, 463.

The conglomerates and arkoses were laid down subaerially by the disorganized river systems then existing.

When volcanic activity had ceased and erosion had proceeded for some time, a series of carbonaceous muds, sands, and gravels (Queen Charlotte Islands formation) was deposited in chiefly brackish water estuaries and local shallow lake basins, in which fish lived. A temperate climate is indicated by the plant remains found in the formation and the topographic development of the land surface had probably reached at least a stage of maturity.

Following sedimentation, epeirogenic uplift, local deformation, and batholithic intrusion ensued, which resulted in the close folding and faulting particularly of the Lower Cretaceous(?) deposits. The broad emergence of the land commenced a new cycle of erosion and this portion of the Cordillera underwent continued denudation and supplied much material for the bordering Upper Cretaceous geosynclinal seas to the east and west.

The Cretaceous erosion cycle removed most of the cover of the late Jurassic granitic batholiths in the Coast range and elsewhere, for the early Tertiary sediments are found resting directly upon them in many places. By the close of the Mesozoic, erosion is thought to have brought the land area down to a state of old age and peneplanation. The ancestral Thompson and Fraser rivers flowed then as now into the Pacific and their present courses transverse to the regional structure are thought to have persisted from courses developed during this Cretaceous erosion cycle (antecedent rivers).

Following the deposition of great thicknesses of sediments in the Cretaceous geosynclinal seas, crustal unrest commenced which culminated later in the 'Laramide revolution.' This was in the nature of regional upwarping and the broader orograpic features of the Cordillera were probably outlined about this time. In some coastal regions, however, both to the east and west there was continuous sedimentation as borne out by conformable relationships between Upper Cretaceous and early Tertiary sediments. The climate in the mountains, then, was probably cool and humid and in possibly the eastern portion of the Coast range and in the Columbia mountains which happened to be loci of maximum uplift, conditions may have been favourable for the support of alpine glaciers. The presence of boulders and pebbles similar to those of glacial origin found in the early Tertiary sediments of the Columbia mountains suggests such an inference. The major Cretaceous rivers emptying into the Pacific ocean maintained approximately their western courses throughout this epeirogenic uplift of the Cordillera. The 'Laramide revolution' as the name would imply, resulted in some overthrusting and faulting in the eastern portion of the Cordillera and commenced the growth of the physiographically youthful Rocky mountains.

The Laramide revolution began a new cycle of erosion; the drainage became invigorated and the rivers were deeply entrenched within the older Cretaceous erosion surface. Denudation proceeded rapidly with continental sedimentation in local lake basins where vegetation flourished (later to be formed into coal) under moist, possibly warm, climatic conditions. With later subsidence aggradation of the valleys set in and early Tertiary sediments were laid down both as delta and river deposits as, for instance, at the mouth of the Eocene ancestor of the Fraser river (Puget group) and in portions of the ancestral Thompson river as recorded south of Savona and Walhachin (Coldwater group). Local volcanic vents supplied rhyolitic lavas (Ashcroft rhyolite porphyry) and acidic tuffs which are frequently associated with the early Tertiary formations. They were largely responsible for the disorganized nature of the drainage in many localities as evidenced by the intimate association of rhyolitic flows, arkosic grits, conglomerates, and acidic tuffs.

During the Oligocene which continued the erosive work of the Eocene, eleva-

tion and local deformation of the early Tertiary formations took place. This post-Coldwater orogeny (probably the post-Kenai revolution of Alaska) further affected the eastern front of the Rockies causing renewed overthrusts and faults[1]. It inaugurated a new cycle of erosion which removed vast records of the early Tertiary.

Volcanic activity broke forth on a grand scale in the early Miocene, and great volumes of basaltic and andesitic lavas, agglomerates, breccias, and tuffs (Kamloops Volcanic group) were poured out into depressions upon the Oligocene and older erosion surfaces. This extravasation of lavas was widespread and affected large tracts of country.

Crustal warping with local buckling and faulting took place probably in the Middle Miocene which threw the eastern portion of the generally flat-lying Kamloops Volcanic group into broad anticlinal domes with intervening synclinal basins, the latter at present preserved on the hill tops. The alkalic intrusions and extrusions of the Boundary and West Kootenay districts may be referred to this period of crustal unrest.

Mid-Miocene diastrophism brought about a most important erosion cycle from the standpoint of the present topography. It lasted during a long period of crustal stability from the middle of the Miocene to near the close of the Pliocene and resulted in the production of an erosion surface of mature and late mature relief in the Coast range and Columbia mountains and a peneplain (present upland surface) in the intervening tracts of Interior Plateau. It probably did not, however, reach the perfection and extent of the previous Cretaceous erosion surface.

The climate was gradually becoming cooler. The Tertiary closed and the Quaternary period began with a great regional upwarping of the Pliocene erosion surface. The uplift, which was of a differential character, varied in degree from place to place perhaps averaging about 4000 feet. The drainage was rejuvenated and the master streams on the Pliocene erosion surface became deeply entrenched, resulting in the present youthful valleys.

During the Pleistocene refrigeration of climate, the Cordilleran ice sheet advanced and retreated leaving much drift. At least two distinct periods of valley glaciation and alluviation succeeded the disappearance of the ice cap.

The retreat of valley ice increased the eroding activity of the streams which began the dissection of the alluvial gravels, sands, and silts. This process of dissection, still active, was probably further aided by regional uplift.

Summarized Geological History of the Region.

The geological history of this region may be presented for the sake of conciseness in the following tabular scheme:—

(1.) Downwarp of a mid-Palæozoic peneplain with the transgression of a Devono-Carboniferous epicontinental sea. Probably warm tropical climate. General marine sedimentation with local vulcanism (Câche Creek group).

(2.) Uplift and local deformation of coastal plain deposits toward the close of the Palæozoic; followed by cycle of erosion. Humid cool climate(?). Moderate relief. Organized drainage. Continuous sedimentation in some coastal regions.

(3.) Transgression of Jura-Triassic sea. Probably semi-arid climate. Marine sedimentation in shallow seas accompanied by pronounced igneous activity (Nicola group).

4. Orogenic uplift—'Jurassic revolution.' Birth of Sierra Nevadas and Coast range and batholithic intrusions of the Pacific coast (granitic intrusives). Youthful topography. Rapid subaerial erosion. Chiefly consequent drainage followed by subsequent, etc.

[1] Summary Report, Geol. Surv., Can., 1910, p. 157.

(5.) Jura-Cretaceous continental sedimentation and widespread volcanic activity. (Spence Bridge Volcanic group.) Semi-arid climate. Rugged probably fine textured topography with many volcanic peaks. Disorganized drainage.

(6.) Lower Cretaceous sedimentation in brackish waters and in part marine. (Queen Charlotte formation). Cool humid climate.(?) Mature topography.

(7.) Epeirogenic uplift and local deformation with possibly granitic intrusions. Followed by Cretaceous cycle of erosion during long period of crustal stability in which the land surface was brought down to a peneplain. Coarse textured topography. Transverse courses of Thompson and Fraser rivers inherited from this Cretaceous peneplain.

(8.) Laramide revolution. Epeirogenic upwarp of Cretaceous peneplain with maximum uplift along the axes of present mountain ranges. Probably humid, cool climate. Continuous sedimentation into the Tertiary in some coastal regions.

(9.) Early Tertiary continental erosion and sedimentation (Coldwater group) with local rhyolitic eruptions (Ashcroft rhyolite porphyry). Moist semi-tropical climate(?). Major streams antecedent with slightly different courses than at present. Drainage rejuvenated and much of it disorganized with many local lake basins. Development of topography from state of youth through adolescence to post maturity.

(10.) Oligocene diastrophism. Widespread elevation with intense local deformation (possibly birth of Rocky Mountain system proper). Followed by Oligocene erosion cycle which removed much of the early Tertiary rock record and paved the way for later planation. Semi-tropical climate.

(11.) Lower Miocene volcanic activity. (Kamloops Volcanic group.) Slight topographic relief. Drainage locally disorganized by lava flows.

(12.) Mid-Miocene crustal warping with local buckling and faulting of lower Miocene volcanics. Probably intrusion and extrusion of alkalic rocks to the south and east in the Boundary and West Kootenay districts.

(13.) Late Miocene and Pliocene cycle of erosion during long period of crustal stability. Production of peneplain in the Interior Plateau and mature to post-mature erosion surface in bordering mountain ranges (old upland erosion surface). Coarse textured topography in Interior Plateau and finer textured in Coast range. Climate becoming cooler. Drainage well organized.

(14.) Differential uplift of epeirogenic character in late Pliocene or early Pleistocene. Uplift slow enough for antecedent streams some of whose courses were inherited from a Cretaceous peneplain, to maintain their general courses. Pre-glacial erosion with deep incision of Pliocene drainage within the upland surface (youthful valleys). Drainage, therefore, antecedent from Pliocene and rejuvenated.

(15.) Pleistocene glaciation. Arctic climate with milder interglacial period. Cordilleran ice cap softened the contours of the old upland topography; steepened the slopes of the youthful valleys and left on its retreat much morainic and outwash material. (Admiralty period of Pacific coast). Followed by slight subsidence with deposition of clay silts in lakes.

A recent advance of valley glaciers (Vashon period of Pacific coast) is recorded which further modified the youthful valleys and supplied considerable till and outwash material. Followed by alluviation and deposition of much gravel, sand, and silt.

(16.) Post-glacial erosion cycle. Uplift. Excavation of valley fill by meandering river into river terraces. Incision of canyons, gorges, and ravines.

(17.) Recent river deposits, land slides, and mud creeps. In the Interior Plateau climate is dry with extremes in temperature; while in the Coast range it is humid and temperate.

SAVONA MAP-AREA, BRITISH COLUMBIA.

(Bruce Rose).

Introduction.

The greater part of the field season of 1912 was spent in a geological examination of the Tertiary rocks about the west end of Kamloops lake, in the vicinity of Savona, under the supervision of Dr. R. A. Daly.

The district lies well within the area of the Interior Plateau of British Columbia, and is favourably situated for a study of the structure, lithology, and chronology of the Tertiary rocks, and of the topographic forms.

An area of 64 square miles was mapped in some detail. Work was not confined to the Tertiary, but a study of the general geology was made. A control was established by a plane-table survey of the main roads and rock contacts. With this as a base a sketch map was made by pacing and from compass bearings. Several side trips were made to compare the Tertiary rocks of other localities of the Interior Plateau with those of the Savona map-area. Field work was carried on alone except for temporary assistance in surveying.

Much valuable help was obtained by intercourse at several times during the season with C. W. Drysdale of the Geological Survey.

Previous work has been done by the Geological Survey in this district and is incorporated in Dr. G. W. Dawson's report on the Kamloops map-sheet. This report served as a very valuable basis for the season's work.

The first month of the season was spent as assistant to Mr. Charles Camsell in the Similkameen and Nicola valleys, where an opportunity to study Tertiary basins was offered.

Summary and Conclusions.

The Tertiary history of the Interior Plateau was one of predominant vulcanism, with intervening periods of erosion and fresh-water deposition. Crustal movements were of an epeirogenic rather than of an orogenic nature.

Volcanics and fresh-water sediments are widely distributed but of a very diverse nature from point to point. Vulcanism and deposition while general over a wide area were confined to local basins and were of short duration at single periods. Thus while a few broad generalizations can be made regarding the nature of the rocks, concise descriptions will apply only to the particular section for which each is made.

The three divisions of the Miocene designated by Dawson as the 'Lower Volcanic group,' the 'Tranquille beds,' and the 'Upper Volcanic group' were found to be only separate phases of one series, for which the name 'Kamloops series' is proposed.

Both the Miocene rocks and the underlying Triassic rocks are composed largely of lavas and volcanic ejectementa and in many places are difficult to distinguish from one another. In general the older rocks are more compact and at the same time more shattered by folding and faulting.

The plateau like nature of the uplands of the region and the accordance of altitudes of the main mountain masses indicate that at one period a state of peneplanation was reached which corresponds roughly to these uplands. The time of

this peneplanation is placed by Dawson in the early part of the Tertiary period. It is the opinion of the writer that it occurred not in the early Tertiary but after the latest Tertiary formations had been deposited and hence is tentatively placed as Pliocene. The chief evidence for this is that in several rather widely separated areas the latest Tertiary rocks (upper Miocene of Dawson) are tilted at angles from 20 to 30 degrees and truncated by the general level of the plateau surface.

General Character of the District.

Topography.

The Savona map-area is located in the valley of the Thompson river at the west end of Kamloops lake, and is in the centre of the southern portion of the Interior Plateau of British Columbia. As seen from the valley it appears mountainous. The difference of elevation between the valley bottom and the mountain tops is about 3,500 feet. Kamloops lake has an elevation of 1,120 feet above sea-level and the mountains seldom reach 5,000 feet above sea-level. From the higher points an accordance of altitude of many plateau surfaces appears. Deep valleys separate these plateaus from one another. The valleys have been formed by erosion so that the broad flat-topped mountain masses are mountains of denudation. That the upland surfaces are the remnants of a peneplain is generally recognized. The topography of the uplands is mature but has been slightly modified by glaciation so that hollows containing small lakes or ponds are common.

Five stages of development in the production of the present topographic forms can be recognized.

(1.) *Peneplanation.*—This is shown in the accordance of altitude of the broad flat-topped mountain masses.

(2.) *Mature Valley-cutting.*—Following peneplanation the streams were given renewed erosive power due to uplift, and mature valleys were cut. These are marked by abandoned stream courses and by mature upper slopes of the present valleys.

(3.) *Broad Valley-cutting.*—A second uplift gave the streams renewed erosive power. Certain streams gained an ascendancy over the others and captured their waters by lateral stream piracy. During this stage the greater part of the lower valleys was excavated.

(4.) *Glacial Deepening.*—The valley slopes are steeper towards the streams. Glacial striae mark the rocks. The valley bottoms are filled with re-sorted glacial material and many of the tributary streams are hanging with respect to the main valley.

(5.) *Recent River-cutting.*—Since the retreat of the glaciers and the deposition of glacial material the streams have entrenched themselves in it and terraces have been formed. This is well shown along the Thompson river, which, after leaving Kamloops lake, runs through a gorge cut in silts and gravels.

Particularly fine alluvial fans occur along Kamloops lake at the junction of the small side streams with it.

Climate and Agriculture.

The climate may be described as semi-arid. The rainfall is scanty and the summers are hot. The valleys up to an elevation of 3,000 feet do not receive sufficient moisture for the growth of farm products and above this summer frosts prevent the growth of anything but hay. Below 3,000 feet, trees are very scarce and the slopes are covered with bunch-grass, but above this elevation they become thicker and the upland plateaus are fairly well wooded. The woods are seldom

dense but consist of bunches of trees with open grassy areas between, and are popularly called 'Park Country'. Grazing has been the chief industry for years, and the country is well suited for this. Within the last few years, however, the lower flats, terraces, and alluvial fans are being cultivated for fruit and potato raising, for which irrigation is necessary. The results have been very satisfactory and the amount of land which can be cultivated is limited only by the water supply.

General Geology.

The oldest rocks in the region examined are Triassic in age. They underlie all the younger formations. Tertiary rocks occupy the interstream plateaus and at one time doubtless covered the whole area, but have since been removed in places by erosion. The greater part of the area is mantled with Quaternary gravels and clay.

In general, Dawson's terminology is used and the new term 'Kamloops series' is added. The following table summarizes the formations:—

Table of Formations.

Volcanic and Sedimentary.		
Pleistocene and recent		Gravel, sand, silt, and boulder clay.
Miocene (?)	Kamloops Series:—	
	Upper Volcanic group	Lavas, agglomerates, and andesitic dyke-rock.
	Tranquille beds	Stratified tuffs.
	Lower Volcanic group	Chiefly basalts and porphyrites.
Oligocene	Coldwater series	Conglomerates and sandstone.
Triassic	Nicola series	Chiefly agglomerates and basalts; some limestone.
Plutonic.		
Miocene or Post-Miocene		Small, isolated exposure of granite.

Nicola Series.

The Nicola series consists of basalts, agglomerates, tuffs, felsites, limestones, and argillites. Grey to black basalts and greenish to purplish agglomerates predominate. Tuffs constitute a very minor part of the series and generally grade into agglomerates. Felsite was noted in but one section. Isolated patches of limestones and argillites occur along Deadman river and east of Threemile creek; these contain Triassic fossils.

The rocks are everywhere roughly stratified or interfingered. They are much folded and faulted and are considerably metamorphosed. The volcanics are compacted and shattered by jointing, calcite and quartz stringers commonly occupy the joint-planes; basalts are serpentinized and limestones marbelized, but the metamorphism has not been great enough to produce schists.

The thickness of the series in this area is approximately 10,000 feet.

Coldwater Series.

The Coldwater series consists for the most part of conglomerates. Associated with the conglomerates and grading into them are a few beds of sandstone. No shales were found, but Dawson describes the same series in the valleys of Nicola river and Hat creek where sandstones and shales with coals and lignites lie above the conglomerates[1].

[1] Dawson, G. M., 'Report on the area of the Kamloops Map-sheet, British Columbia.' Annual Report, Geol. Surv., Can., vol. VII, 1894, p. 69B.

The conglomerates are grey to red in colour and are composed of well rounded boulders and pebbles which vary from 2 feet to 1 inch in diameter and even pass into sandstones. The matrix is a clay which in places grades to argillaceous sandstone. The boulders and pebbles are derived from the underlying Triassic rocks and are chiefly igneous, but some pebbles of limestones and argillites are present. A considerable thickness in an area west of Copper creek is made up of quartzite pebbles which are not like any of the Triassic rocks and are supposed to have been derived from the Cache Creek beds[1].

The greatest development of the conglomerates is in a band parallel to Copper creek on its west side. Here they dip northeast at angles from 60 to 90 degrees and the outcrop is 2 miles in width so that approximately 10,000 feet of beds are exposed. This figure, however, may be too large for the thickness of the series, as the area is drift covered and the beds may be repeated by faulting. In an area south of Kamloops lake the beds are nearly horizontal.

The Coldwater series intervenes between the Triassic rocks and the Miocene volcanics and has been placed as Oligocene by Dawson.

Kamloops Series.

'Kamloops series' is a name proposed to include the Lower Volcanic group, the Tranquille beds, and the 'Upper Volcanic group' of Dawson. Wherever examined the Tranquille beds pass comformably into the Lower Volcanic group below and the Upper Volcanic group above, so each represents a stage in the formation of a single series. The thickness of the series in the Savona map-area is approximately 4,000 feet.

Lower Volcanic Group.—'Lower Volcanic Group' is a name applied by Dawson to a great thickness of volcanic rocks which unconformably overlie the Coldwater conglomerate. Three areas mapped by him were examined, and in no case were the rocks sufficiently alike to be correlated. One area in the vicinity of Spence Bridge, where there is a large development of these rocks, consists of flows of red, black, and green basalts and porphyrites with some agglomerates. Another area at the mouth of Tranquille river north of Kamloops lake, consists of interbedded basalts and tuffs, which grade into typical Tranquille beds and are thought by the writer to belong to the same series as the Tranquille beds. A small area at the mouth of Copper creek consists of greenish agglomerates, grey tuffs, augite porphyrites, and serpentine. These resemble the Nicola series more than they resemble the Lower Volcanic group, so it is doubtful if any rocks of this group occur in the Savona map-area.

Tranquille Beds.—The Tranquille beds consist largely of well stratified yellow and grey tuffs and tufaceous agglomerates containing in places thin beds of lignite and carbonaceous shale, and if the writer's interpretation of the rocks at the mouth of Tranquille river be correct, they include at the base several basaltic flows. The stratified tuffs contain fossil leaves and fishes and have been classified both as Oligocene and Miocene. A few specimens of well preserved fossil fishes were found at Red point on Kamloops lake. It is hoped that the identification of these will settle the age of the Tranquille beds. In the Savona district these beds have a thickness of 700-800 feet.

Upper Volcanic Group.—The Upper Volcanic group consists of inter-layered and inter-fingering basaltic lavas and agglomerates which are cut by dykes of andesitic rock. Owing to the discontinuity of the individual beds measurements of different sections do not correspond. A section from Savona mountain is as follows:—

[1] Dawson, G. M., 'Report on the area of the Kamloops Map-sheet, British Columbia'; Annual Report Geol. Surv., Can., vol. VII, 1894, p. 70B.

Red, grey, and black, vesicular and columnar basalts..	600 feet.
Basaltic agglomerates and breccia..................	800 "
Black and red vesicular basalts and agate geodes.....	900 "
Agglomerate with grey tuff matrix..................	200 "
Total........................	2,500 feet

In another section the agglomerate with tuff matrix measured 1,000 feet so that the thickness of the Upper Volcanic group approximates 3,300 feet.

Pleistocene and Recent.

Unconsolidated gravels, sands, silts, and boulder clays mantle the greater part of the surface. Boulder clays cover most of the upland surfaces and at one point reach the level of Kamloops lake. Resorted glacial material consisting of well stratified gravels, sands, and silts, fills the valley bottoms and has been cut into a series of terraces. Alluvial fans are common at the mouth of the tributary streams. They are especially well developed along Kamloops lake.

Economic Geology.

Mercury.—Deposits of cinnabar occur at intervals along a zone extending from Criss creek north of Kamloops lake to Toonkwa lake south of Kamloops lake, a distance of 22 miles. More work has been done on a property at the mouth of Copper creek than any other. Here the ore is in a band of rusty dolomites associated with agglomerates, tuffs, and porphyrites. The cinnabar is in irregular veins of quartz and calcite and is associated with small amounts of stibnite and chalcocite. Many outcrops of low grade ore of uncertain value and a few of high-grade ore are exposed. This deposit was mined and 114 flasks of mercury were retorted from high-grade ore. A furnace was built to treat high-grade ore, but did not work satisfactorily and the works were closed in 1897.

Copper.—A number of copper prospects are located immediately east of Copper creek in an area of sandy tuffs belonging to the Tranquille beds. The tuffs are cut by a large dyke or sheet of augite porphyrite, and both this and the tuffs by basic dykes. The basic dykes are the ore bearers. Mineralization has taken place in numerous small fissure veins where the basic dykes cut the porphyrite. The ore is bornite and chalcopyrite associated with quartz and calcite, and carries some gold and silver. So far no body of ore of sufficient extent to justify mining operations has been exposed.

Gold.—The gravels in most of the stream courses carry small values in gold. The deposits at the junction of Deadman and Thompson rivers have been worked as placers but nothing to justify large operations is known.

Limestone.—Several beds of limestone near Threemile creek are suitable for the production of lime. The limestones and argillites along Deadman river may prove to be valuable for the manufacture of cement.

Clay.—Stratified silts or clays suitable for the manufacture of brick are widely distributed in the valley bottoms. In conjunction with the limestones they can be used in the manufacture of cement.

GEOLOGY OF THE SELKIRK AND PURCELL MOUNTAINS AT THE CANADIAN PACIFIC RAILWAY (MAIN LINE).

(*Reginald A. Daly.*)

Introduction.

The writer spent the season of 1912 in continuing the transmontane section begun the previous year (Summary Report for 1911, pp. 165-174). The work consisted essentially in a structural analysis of two great terranes. One of these is the Beltian-Cambrian sedimentary series (Rocky Mountain geosynclinal) comprising the Purcell Mountain system and all but the western part of the Selkirk Mountain system. The other is the Shuswap terrane, unconformably underlying the Beltian strata at Albert Canyon.

Stratigraphy.

The formations encountered in the section from Revelstoke to Golden are the following:—

		Thickness in Feet.
Recent	River gravels and sand.	
Pleistocene	Glacial drift.	
	Unconformity.	
Ordovician (?)	Unfossiliferous beds in Rocky Mountain Trench.	
Upper Cambrian or Ordovician	Fossiliferous limestone and shales, exposed at railway 2 miles west of Donald station.	
Middle Cambrian	(Failure of outcrop).	
Lower Cambrian	Sir Donald quartzite	5,000±
	Ross quartzite (upper part)	2,750
Beltian	Ross quartzite (lower part)	2,500
	Nakimu limestone	350+
	Cougar quartzites	10,800+
	Laurie metargillites	15,000+
	Illecillewaet quartzite	1,500
	Moose metargillite	2,150
	Limestone	170
	Basal quartzite	280
	Unconformity.	
Pre-Beltian (Shuswap terrane, including the Shuswap sediments and the intrusive granites.)	Granitic dykes, sills, laccoliths, and batholiths cutting the following.	
	Adams Lake greenstones	10,000+
	Tshinakin limestone and metargillite	3,900
	Bastion schists (phyllites, etc.)	5,000+
	Sicamous limestone	3,200
	Salmon Arm mica schists	1,800
	Chase quartzite	3,000
	Tonkawatla paragneiss (?)	1,500+
		69,900+

The only post-Shuswap intrusive rocks observed are dykes of minette, one diorite dyke, and a thin sill-dyke of highly vesicular basalt, cutting the Laurie metargillite at Albert Canyon.

SHUSWAP TERRANE.

Detailed work has been only begun on the widely exposed pre-Beltian rocks which form the crystalline basement of British Columbia and share the complexity of the 'Archæan' in all parts of the world. They consist of a very thick, conformable, bedded group called the *Shuswap* series, and a younger group of granitic intrusives. The whole complex may be conveniently named the Shuswap terrane.

Shuswap Series.

Owing to structural difficulties, to the ruggedness of the mountains, and especially to a dense forest cover, it has not yet proved possible to construct a definitive columnar section for the Shuswap series. It is best exposed on the shorelines of the Shuswap lakes and of Adams lake during the low-water season of the year. However, one can seldom follow a contact or other structural plane far from the lake shore. Faults, thrust-planes, and folds are unusually difficult to map in this thoroughly metamorphosed mass of sediments and volcanics. Neither the top nor the bottom of the series has been found. The oldest sediments are interleaved with, and underlain by, intrusive granites, chiefly developed as sills. The youngest member, on Adams lake where it is best exposed, is truncated by the present erosion surface.

Obscure as the structures generally are, it is quite clear that the Shuswap series is exceedingly thick. Its columnar section, given above, is provisional; it combines facts discovered during the last two seasons.

The *Tonkawatla formation* is exposed in a series of railway cuts 3 miles west of Revelstoke. It consists of a dark-coloured, massive, homogeneous, comparatively fine-grained gneiss bearing thin interbeds of white crystalline limestone. The latter are seldom over 2 inches in thickness but are locally numerous. Their presence suggests that the whole group of rocks here exposed is of sedimentary origin. The gneiss is rich in biotite and plagioclase and is probably best interpreted as originally a calcareous argillite. The paragneiss passes upward into yet more massive, harder, biotitic quartzite, which also carries thin intercalations of limestone.

Quartzite of identical habit and tentatively ascribed to the same horizon, is exposed on the slope due south of Shuswap station, near the village of Chase. Here the thickness is to be measured in hundreds of feet and a special name, *Chase quartzite*, has been given to the member. Besides the thin beds of limestone, the quartzite often shows abundant disseminated grains of carbonate, largely calcite.

At Shuswap station the massive Chase quartzite is directly overlain by coarse glittering muscovite-biotite schist, often garnetiferous and seamed with beds of micaceous quartzite. As usual in the Shuswap series, the planes of bedding and schistosity are coincident. A thickness of some 1,500 feet is locally represented in these schists. They appear to be of the same horizon as a group of schists exposed in still greater strength on Salmon Arm of Shuswap lake; the name *Salmon Arm schist* may be given to the member. The coarse crystallization of the plainly sedimentary formation is due to the contact metamorphism of countless granitic sills and laccoliths. On the cliffy slopes at the eastern end of Bastion mountain the coarse schists pass up gradually into phyllite, a less metamorphosed phase.

On the slope just mentioned the Salmon Arm schists are conformably overlain by the thick *Sicamous limestone*, named for its occurrence at Sicamous station. This is a thin-platy, light bluish-grey to dark grey or almost black limestone generally interrupted by closely spaced sericitic films. The range in colour tints is due to variation in the amount of carbonaceous matter disseminated through the limestone. The rock effervesces with cold dilute acid but it is somewhat magnesian.

The western slope of Bastion mountain is in part underlain by the *Bastion schists*, conformably overlying the Sicamous limestone. These are best exposed on the shore of the lake, north of Canoe point opposite Sicamous. They are chiefly sedimentary phyllites but at the top are green schists, apparently of volcanic origin.

On Adams lake, schists like the last mentioned rocks are conformably overlain by the composite *Tshinakin formation*, which, in turn, is there conformably overlain by a gigantic series of greenstones and green schists, the *Adams Lake formation*, enclosing rare interbeds of limestone and phyllite. To this youngest recognized member of the Shuswap series Dawson gave the name 'Adams Lake series,' and he regarded it as of Cambrian date and of volcanic origin. More recent work has referred it to the pre-Beltian series. Dawson estimated the thickness of these volcanics as 25,000 feet; the apparent thickness is certainly greater than 10,000 feet.

No complete field section has yet been found in the great Shuswap terrane and several of the horizons have been brought into the described relations through lithological similarities in different sections. That principle is of specially hazardous application in a region of complete metamorphism like that now under consideration. The table of formations will, therefore, surely need emendation. Nevertheless, it will serve to give a picture of the leading stratigraphic inferences so far made and to indicate in a qualitative way the magnitude and variety of the formations composing the Shuswap series.

Orthogneisses and Intrusive Granites.

Without exception each member of the Shuswap series has been intruded by granitic magma of pre-Beltian age. Some of the largest of these intrusive bodies seem to be true batholiths which have developed strong metamorphic aureoles. However, most of the intrusions, literally innumerable, are not subjacent or bottomless but are to be classed with the 'injected' bodies. Sills are specially conspicuous. Some of the injections are very thick and apparently of laccolithic form and mechanism; others have roofs and floors but cross-cut the bedded formations and these may be described as chonoliths. Dykes are very numerous, in part representing the feeding channels for the other types of injection.

The injected bodies are, in part, clearly satellites of underlying batholiths, but it is possible that many of them are due to the migration of hydrous magmas locally generated in the depths of a greatly metamorphosed terrane.

The principal petrographic types in these intrusions are: biotite granite (most abundant); hornblende-biotite granite; two-mica granite (rare); pegmatite and aplite (both very abundant); and orthogneisses corresponding to each of these magmatic species. Extended microscopic study shows that there is little mineralogical novelty; the rock types are duplicated in most of the 'Archæan' tracts on the globe.

The extraordinary prevalence of sills and other concordant injections is explained by the extreme fissility of the Shuswap sediments and greenstones. This feature is due to static metamorphism, as explained in the Summary Report for 1911. It seems highly probable that the fissility had attained nearly its present perfection before the Beltian system of rocks was deposited on the Shuswap terrane, and thus at an early date in the earth's history. The conditions for the metamorphism include: deep burial, with consequent development of 'stress' in the vertical direction; and an abundant supply of interstitial water, such as that originally trapped in the sediments and volcanic beds. The completeness of recrystallization, which is much more striking than that visible in similar

geosynclinal rocks of Cambrian or later date, implies that at least one other condition was here necessary. Hypothetically, we may find it in a specially steep thermal gradient, controlling subsurface temperatures in pre-Beltian time. Field evidence thus leads to the suspicion that the earth was then notably hotter than it was later, when most of the known thick masses of sediments were deposited.

Whatever be the explanation, it is clear that the Shuswap series has not been seriously affected by dynamic metamorphism. The strata were completely or almost completely recrystallized while they lay nearly flat. In some localities the effects of dynamic metamorphism have been superposed on those due to previous static metamorphism. Similarly, thermal metamorphism produced by sills or batholiths is generally easy to distinguish from the prevailing regional type. Contact action has either coarsened the grain of the invaded formation or has developed hornfels-borne minerals characteristic of plutonic contacts. The older members of the Shuswap series are, in general, more coarsely crystalline than the younger partly because of deeper burial but more because of the greater abundance of intrusions at the lower horizons.

BELTIAN SYSTEM.

Unconformably overlying the Shuswap terrane in the Selkirk mountains, is a vast thickness of conformable, unfossiliferous sediments, to which as a whole the name, *Selkirk series*, has been given. The lower and greater portion of these beds is of Pre-Cambrian age; the uppermost beds, as exposed in the railway section, are referred, on stratigraphic evidence, to the Lower Cambrian. The group is clearly the northern continuation of the Belt series of Montana and Idaho. To the Pre-Cambrian portion of each series Walcott has applied the name 'Beltian' as a systemic designation and it will be adopted for present use.

In the railway section the Beltian is constituted of the following members:—

Columnar Section of the Beltian System in the Selkirk Mountains.

	(Top, erosion surface.)	*Approximate thickness in feet.*
Glacier division (Selkirk series of Dawson)	Ross quartzite (in part)	2,500
	Nakimu limestone	350
	Cougar formation (quartzite with metargillitic beds)	10,800
Albert Canyon division (Niskonlith series of Dawson)	Laurie formation (metargillite, often calcareous; with subordinate interbeds of limestone and quartzite; basal bed, grey limestone 15 m. thick)	15,000+
	Illecillewaet quartzite	1,500
	Moose metargillite	2,150
	Limestone (marble)	170
	Basal quartzite	280
		32,750
	(Base, unconformity with Shuswap terrane.)	

In the railway section the *basal quartzite* is a greenish-grey, fine-grained metarkose, a massive to well-bedded, feldspathic rock of quartzitic habit, though strongly charged with films of sericitic mica. The original material was the somewhat washed sand due to the secular decomposition of the underlying Shuswap orthogneiss.

At its top the quartzite is interleaved with the lowest layers of the overlying limestone. This is a thin-bedded to thick-bedded, white to bluish marble, generally weathering to a pale buff colour. It is magnesian throughout, though some beds are more purely calcitic than others.

The *Moose metargillite* has been so designated from an older name of Albert creek, which enters the Illecillewaet river at Albert Canyon station. The middle part of this formation has not yet been found in satisfactory exposure but the whole seems to be a fairly homogeneous argillite now largely recrystallized by static metamorphism—a metargillite. All phases are charged with sericite developed parallel to the bedding planes and occasionally one finds thin beds glittering with coarser mica like a normal muscovite schist. The colour is generally grey of a dark tint due to disseminated particles of carbon.

The *Illecillewaet quartzite* is hard, grey, massive to fissile, and relatively homogeneous except for thin intercalations of metargillite. Unlike the basal quartzite, it is poor in feldspathic material and evidently represents a more completely washed and assorted sediment.

In the monoclinal section between Albert Canyon and Ross Peak stations, the *Laurie formation* (named after the mining camp at the railway) is of most remarkable thickness. Measurement on the actual outcrops gave the following succession:—

Columnar Section of the Laurie Formation.

(Base of the Cougar formation).	*Approximate thickness in feet.*
Grey, phyllitic metargillite	4,000
Quartzite	650
Black to dark grey metargillite	500
Alternating beds of phyllite and quartzite	750
Black to dark grey, carbonaceous, often pyritous metargillite, with interbeds of blackish limestone	9,300
Grey quartzite	400
Black to dark grey, strongly carbonaceous metargillite, with numerous interbeds of blackish limestone	3,500
Massive, light grey limestone	50
	19,150

(Top of Illecillewaet quartzite.)

There is no sign of important duplication by strike-faulting, though some thickening is represented in local crumples. Admitting all possible duplication suggested by the facts now in hand, this formation must be credited with a thickness of more than 15,000 feet. On account of the general uniformity of composition and habit, no satisfactory subdivision of the formation is yet feasible; because of their limited exposure in the railway zone, the quartzitic beds cannot be used for subdividing.

The Albert Canyon division of the Selkirk series is, thus, chiefly of metargillitic composition. The overlying Glacier division, more especially as it crops out on the western slope of the Selkirk range, is dominantly quartzitic.

Its most heterogeneous member is the *Cougar formation*, named from Cougar mountain, in which it is exposed on a great scale. In the monocline between Caribou creek and the Caves of Cheops (Nakimu), the formation shows the following general succession:—

Columnar Section of the Cougar Formation.

(Conformable base of the Nakimu limestone.)	*Thickness in feet.*
Grey, thin-bedded to thick-bedded quartzite, weathering rusty; with thin interbeds of phyllite and white quartzite; a few seamlets of crystalline limestone in the uppermost quartzite	5,500
Conspicuous band of white, homogeneous, massive quartzite	300
Massive, light grey quartzite, interrupted by many bands of grey, quartzitic grit and coarse sandstone, and by beds of dark grey, siliceous metargillite; about 1,000 feet (305 m.) from the top, a thick band of massive white quartzite	3,000
Quartzitic and phyllitic, grey sandstone and fine conglomerate with metargillite. Near the middle of this zone, angular fragments of altered basaltic rock (bombs?) enclosed in an argillaceous (?) base were found	900
Altered basaltic lava	50±
Thick-platy to flaggy, sometimes phyllitic, grey quartzite	1,050
	10,800
(Conformable top of Laurie formation.)	

East of the divide of the Selkirk range, the Cougar formation is, on the whole, more thin-bedded and more argillaceous (originally) than in the section just detailed. The equivalent strata of the Rocky mountains—the Corral Creek formation and the lower part of the Hector formation—are still more argillaceous, consisting of grey, green, purple, and black metargillites with interbeds of rusty quartzite. The rocks of this general horizon thus become finer-grained, less purely siliceous, and more argillaceous as the section is followed from west to east. A similar variation characterizes the Rocky Mountain geosynclinal rocks at the 49th parallel section.

The *Nakimu limestone* is specially notable as being the most useful horizon-marker in the Selkirk and Purcell mountains. It is truly protean in lithological features, but one is seldom at fault in identifying it in the field. The Caves of Cheops (Caves of Nakimu) have been formed by solution and by the mechanical erosion of Cougar creek, as it follows for some distance a subterranean course in the formation. At that most westerly outcrop the formation is a light grey, fine-grained crystalline limestone. The rock is comparatively homogeneous but carries disseminated sericitic mica in many beds. In the outcrops of the eastern Selkirks and of the Purcell mountains, the same grey type of limestone is interbedded with blackish, very carbonaceous limestone and with rusty-weathering, sandy or pebbly, dolomitic limestone. The thickness is quite variable—from as much as perhaps 600 feet at the Caves of Cheops to a few feet near Beavermouth. These differences are in part original; in part they seem to be due to squeezing out during the uplift of the mountains.

The Nakimu limestone is conformably overlain by the thick *Ross quartzite*, named from Ross peak, a mountain opposite Cougar creek at its confluence with the Illecillewaet river. The lower part of this formation is of Pre-Cambrian age; the upper part is probably to be assigned to the Lower Cambrian. All these admirably exposed beds are conformable, not only with one another but also with the definitely Lower Cambrian Sir Donald quartzite above.

In the section between the Caves of Cheops and Rogers Pass station near the summit of the Selkirks, the Ross formation is relatively homogeneous, with composition as here indicated:—

Columnar Section of the Ross Formation.

(*Conformable base of the Sir Donald quartzite*).	*Thickness in feet.*
Grey, rarely rusty, thick-bedded, compact quartzite, with interbeds of grey and brownish quartzitic sandstone and grit	1,200
Pale rusty-brown siliceous phyllite or sericitic quartzite, carrying in the middle a 15-metre bed of grey quartzite	350
Grey quartzite, thick-platy and homogeneous, weathering grey and rusty; with interbeds of hard quartzitic grit and sandstone (in part Lower Cambrian)	3,700
(*Conformable top of the Nakimu limestone.*)	5,250

In the grand exposures along the northwestern edge of Beaver River valley the Ross formation weathers more uniformly rusty, but is still quartzite; this section shows an approximate thickness of 5,000 feet. At the summit of the Dogtooth mountains, the formation is more argillaceous, while retaining its deep-rusty colour and numerous bands of fine quartz conglomerate or grit so characteristic in the Selkirks. It is correlated with the shaly to sandy beds in the upper part of the Beltian Hector formation and in the Lower Cambrian Fairview formation—both exposed in the Bow River valley of the Rocky mountains. Here again the geosynclinal rocks in the east are more argillaceous than those contemporaneously deposited in the west.

CAMBRIAN SYSTEM.

At the summit of the Selkirk range the Ross quartzite passes gradually upwards into the *Sir Donald formation.* This is a very homogeneous mass of quartzite, much like the more siliceous phase of the Ross but here weathering with a grey, rather than a rusty, surface. On fresh fractures the Sir Donald quartzite varies in colour from white, through pale grey and greenish-grey to dark grey, rarely rusty. It is characteristically thick-bedded. Like the Ross formation it is often feldspathic and is charged with numerous lenses of quartz-feldspar grit and fine quartz-feldspar conglomerate. Near the base there is a 160-foot band of pale-rusty to grey quartz-sericite schist.

The Sir Donald quartzite forms most of the highest summits of the Selkirk mountains and is terminated above by the present erosion surface. It has yielded no fossils but clearly represents the fossiliferous Lake Louise and St. Piran beds of the Rocky mountains. The Lower Cambrian Mount Whyte formation of the Rockies may also be correlated, tentatively, with the upper beds of the Sir Donald quartzite.

The general correlation of formations in the Selkirks and Rockies may be stated as follows:—

	Selkirk Mountains.	*Thickness in feet.*	*Rocky Mountains.*	*Thickness in feet.*
Lower Cambrian.	(*Erosion surface.*)		(*Conformable base of the Middle Cambrian.*)	
	Sir Donald quartzite	5,000+	Mt. Whyte formation	390
			St. Piran formation	2,705
			Lake Louise formation	105
	Ross quartzite (upper part)	2,750	Fairview formation	600
Beltian.	Ross quartzite (lower part)	2,500	Hector formation (upper part)	630
	Nakimu limestone	350±		
	Cougar formation (upper part; total thickness is)	10,800−	Hector formation (lower part)	3,960
			Corral Creek formation	1,320
			(*Base concealed.*)	

Structure.

While the Shuswap sediments attained the thickness of a first class geosynclinal, no clear hint has been forthcoming as to the geographical source of their clastic material, nor as to the direction of the major axis of this prism. There is nothing to show that the subsiding trough had the Cordilleran elongation which has been so characteristic of the post-Shuswap geosynclines. In two leading respects the pre-Beltian terrane contrasts structurally with the younger geosynclinals.

The Shuswap series is less deformed than any of the overlying series, up to and including the Triassic. In the Selkirks and Interior Plateaus the average dip calculated (from data additional to those used in the 1911 summary) for the beds of the oldest terrane is no greater than 35°, while the averages for large, typical areas of the Albert Canyon division and Glacier division of the Selkirk series, for the Carboniferous, and for the Nicola (Triassic-Jurassic) series, are, respectively, about 38°, 59°, 73°, and 64°. This is true, though the Shuswap terrane obviously underlay these younger formations when they were passing through several orogenic revolutions. To-day, the Shuswap rocks, in numerous areas each many square miles in extent, are nearly horizontal, while adjacent Carboniferous strata are intensely folded. It appears necessary to believe that the earth-shell which has here transmitted the mountain-building thrust had a depth of only a few miles; and that this shell was sheared over its basement of Shuswap rocks.

The second noteworthy feature is the general failure of the Shuswap strata in actual outcrops to show the Cordilleran trend characteristic of all the younger formations. The prevailing strike of the basement rocks is about N. 70° E., and thus nearly at right angles to the general Cordilleran strike in this latitude. Quite locally the older rocks have been gripped in a post-Carboniferous folding and show Cordilleran strike; such exceptions do not invalidate the general rule. One is reminded of the prevailing E.—W. to N. 60° E. strikes in the Pre-Cambrian rocks of Lake Superior and eastward thereof, in the Canadian shield. Is this agreement of structural trênds, in the two 'Archæan' areas, fortuitous?

As already stated, the detailed structure of the Shuswap terrane offers a host of unsolved problems. In general, the deformation of the bedded rocks seems to have consisted in warping and normal-faulting, especially the latter. The extremely abundant sills and other intrusive bodies seem to have suffered nearly as much deformation as the invaded sediments.

The Beltian and Lower Cambrian strata of the Purcell and Selkirk mountains and their equivalents in the Rocky mountains, with the conformable formations of Middle Cambrian to Permian age, together form a single mass of rocks. In the Selkirks there is perfect conformity between the Lower Cambrian and Beltian systems; in the Rockies their relation is reported to be that of conformity at some contacts and that of moderate unconformity at others. There is no thorough-going unconformity in this gigantic series. It is, in fact, best regarded as a single geosynclinal prism of the first order.

The western slope of the Selkirk range, from Albert Canyon to Glacier, is composed of a gigantic monocline of Beltian-Cambrian sediments affected by local subsidiary folds and rare zones of shearing. This monocline is the western limb of a wrinkled syncline which forms the summit of the Selkirks. Some strike faults affect the syncline without destroying its essential character.

The Purcell trench, followed by the Beaver river, is located on a wide unroofed anticline adjoining the summit syncline. The Purcell mountains (Prairie hills and Dogtooth mountains) represent a regular system of alternating synclines and anticlines made up of Beltian strata (lower Ross to Cougar). The larger

of these folds are, in general, more appressed than the primary folds of the Selkirks or the anticline at the Purcell trench. The axes of almost all of the folds, like the rare normal faults, have the Cordilleran trend, north-northwest—south-southeast.

The Rocky Mountain trench is here located on a longitudinal fault with a vertical throw at least equivalent to the whole thickness of Cambrian sediments in the region (20,000 + feet). The actual trench is due to prolonged erosion in the soft Ordovician and other sediments downfaulted on the east side of the great fault. The ragged mountain escarpment of the Purcells overlooking Golden and Donald shows outcrop of the Beltian formations (Cougar to lower Ross quartzite). At its foot the railway cuttings west of Donald exhibit limestones and shales bearing trilobites determined by Dr. C. D. Walcott as characteristic of the upper part of the Upper Cambrian (perhaps the Ozarkian of Ulrich's classification). Among the organisms one new species of *Dikelocephalus* was here found and will be described by Dr. Walcott. No other fossils were discovered during the season. The correlation of the Selkirk series with the fossiliferous Cambrian of the Rocky mountains is, however, possible through the unmistakable equivalence of the Sir Donald quartzite with the St. Piran quartzite and other Lower Cambrian formations at Lake Louise.

ROCKY MOUNTAIN SECTION BETWEEN BANFF, ALTA., AND GOLDEN, B.C., ALONG THE CANADIAN PACIFIC RAILWAY.

(*John A. Allan.*)

Introduction.

During the field season of 1912 a section was completed across the Rocky Mountains system along the main line of the Canadian Pacific railway. The section extends from Golden, in the Columbia valley on the west, to the Cascade trough near Banff, where it connects with a section of the Cascade basin, made by Dowling [1]. The examination of the geology was made on both sides of the railway, as far as it was necessary to obtain true relations of the various formations. The section on this account varies in width, but an average would be about 4 to 6 miles on each side of the railway. The total area mapped in this section is over 1,000 square miles, of which about 300 square miles were mapped during the field seasons of 1910 and 1911. The mapping was done on a scale of 1 to 62,500, or about 1 inch to 1 mile, and the maps used were enlargements from the Lake Louise and Banff sheets, the Rocky Mountains map, published by the Interior Department.

About three months were spent in the field, of which the first three weeks were devoted to the western part of the section between Golden and Leanchoil, and the Beaverfoot and Van Horne ranges. The remainder of the season was spent east of the Continental Divide. Side trips were made to Ptarmigan pass, Vermilion pass, and Simpson pass.

One complete structure section was made across the entire range of the Rocky mountains. Efficient assistance was rendered by Mr. Alan E. Cameron, and by Mr. C. R. Woodward, who compiled some of the data for the structure sections.

Acknowledgments are due Mr. W. Peyto, of Banff, for valuable information regarding the eastern part of the section, and to Mr. J. Smith, of Castle Mountain, for information on early prospecting done in the district.

Topography.

The general character of the westward slope of the Rocky Mountain system along this section was given by the writer in the Summary Report for 1910, pages 136-137, and for 1911, page 176. The main topographical features will be here noted. These brief remarks may be regarded as supplementary to the much fuller descriptions given by Dawson [2], and by McConnell [3].

The Bow range has a general trend of N. 75° W. which is the direction of all the neighbouring ranges in the Rocky Mountain system. This range is drained to the west by the Kicking Horse river which enters the Columbia river at Golden, and to the east by the Bow river and its tributaries, which enter the Saskatchewan river about 200 miles east of Calgary. The Bow range has a maximum elevation of over 11,600 feet, but the average elevation is about 10,000 feet above sea-level. It contains many of the most majestic mountains in the Canadian Rockies. Among those best known are Mount Temple (11,626 feet), which is surpassed in altitude

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[1] Dowling, D. B., Cascade Coal Basin, Geol. Surv., Can., 1907.
[2] Dawson, G. M., Annual Report Geol. Surv., Can., 1885, p. 124B.
[3] McConnell, R. G., Annual Report Geol. Surv., Can., 1886, pp. 9-13D.

in this section only by Mount Goodsir (11,676 feet), in the Ottertail ranges; Mount Victoria (11,355 feet); Mount Lefroy (11,220) feet; Mount Hungabee (11,447 feet); Mount Ball (10,828 feet); and many others. The Bow range forms the southwestern side of the Bow valley as far to the southeast as Vermilion pass, beyond which it is separated from the main valley by Bourgeau range. The Bow range, however, forms the continental watershed for many miles to the southeast. Mount Assiniboine is one of the best known lofty mountains in this range.

The Bow river has its source in the Bow lakes, over 25 miles northwest of Laggan. It is further supplemented 8 miles down its course by water from Hector lake, which is nearly 3 miles long. The valley of the river is broadly U-shaped as it has been carved out by glacial erosion. It has a southeasterly trend and is subsequent to the substructure for over 50 miles, to Sawback siding, a point 6 miles west of Banff. Here the valley turns sharply to the east and cuts diagonally across the steeply dipping limestones and shales of the Sawback range and other ranges to the east. It assumes this easterly course until it enters the Cascade trough[1] about 2 miles east of Banff.

Between Hector lake and Banff the river is without waterfalls. In some parts of its course well-developed meanders have been formed; in a few places the stream has cut across the necks of the lobes and 'ox-bow' lakes have resulted. Vermilion lake is one example of such a 'cut-off'.

In the vicinity of Laggan there are three valleys entering the Bow valley from the south side, all of which are noted from a scenic point of view. The mouths of these three valleys are hanging from 600 to 800 feet above the floor of Bow valley. These are: valley of the Ten Peaks, Paradise valley, and the short valley which is largely occupied by Lake Louise. All three represent cirques of huge dimensions. Remnants of glaciers are found in each valley and are known by the names Wenkchema, Horseshoe, and Victoria glaciers. The lake which previously occupied the floor of Paradise valley has been drained, but Moraine lake occupies the floor of the first-mentioned valley. This lake is surrounded by ten snow-capped mountain peaks, all of which are over 10,000 feet high.

The north side of the Bow valley is closed in by Castle Mountain range, which extends from the head-waters of the Bow to Castle mountain, where it dies away. This range is continued to the south of the valley by Bourgeau range. This orographic unit is made up in part of Mount Bourgeau, Mount Brett, and Pilot mountain; and by Castle mountain, Ptarmigan peak, Mount Richardson, Mount Hector, and several lower peaks to the north of the valley in the Castle Mountain range.

These two ranges are characterized by their flat-lying massive beds of limestone which vary in age from Cambrian in the Castle Mountain range, to Devonian and Carboniferous in the Bourgeau range.

The next distinct range to the northeast is the Sawback range. It consists of steeply-dipping Devonian and Carboniferous strata. Some of these limestone beds give the southwest face of this range an imposing appearance because the smooth-bedding plane forms the face of the cliff. This range is terminated on the north side of the railway by Hole-in-the-Wall mountain. It is continued to the south of the Bow valley by an unnamed range.

Sawback and Castle Mountain ranges are separated by a depression which is occupied in part by Johnston creek, northwestward-flowing and southeastward-flowing branches of Baker creek, and some of the head branches of Red Deer river. To the south of the railway it is occupied in part by Brewster creek.

The Vermilion Lake range[2] east of the Sawback range, is separated from

[1] So called by Dr. Dawson, Annual Report, Geol. Surv., Can., 1885, p. 126B.
[2] So-called by McConnell, Annual Report, Geol. Surv., Can., 1886, p. 10D.

the latter by the valley of Fortymile creek and Edith pass. This range is also continued south of the Bow valley by Sulphur Mountain ridge, which Dawson calls Terrace mountain on his map.

Cascade range forms the southeastern border of the Cascade trough. It is terminated by Cascade mountain, which is made up of westerly dipping Devonian, Carboniferous, and Jurassic limestones and shales. South of the Bow valley, Mount Rundle and the Three Sisters form the southeasterly continuation of the Cascade range.

Thermal and Other Springs.

The hot sulphur springs, which help to make Banff a favourite resort, are chiefly located along the east slope of Sulphur mountain. There are three strong springs known, two of which are used extensively for bathing purposes. All are located along a strike fault in the Devonian limestone. The upper hot spring is about 600 feet above the town. The water is highly sulphurous and comes from the rock at a temperature of 114·2° F. In winter this temperature is slightly higher. This may be due to the frozen condition of the surface rock and detritus preventing the cold meteoric water from mingling with the warmer water below.

Close beside this spring is another, the water of which is high in lithia and, therefore, has special medicinal properties.

The middle hot spring is about 200 feet lower down and over a mile and a quarter nearer the Bow valley. The temperature of the water in this spring is about 100° F. There is an abundance of brilliantly colored algae growing in the pools formed about the spring.

The lower spring is about 100 feet above the floor of the Bow valley and at the northeastern end of Sulphur Mountain ridge. This spring is situated in a cave, 20 feet in diameter, which it has made for itself in the thick geyser deposits. There is a small hole one foot in diameter in the roof of this cave and through this orifice the steam freely escapes. A pool 2 to 5 feet deep occupies the floor of the cave, and through small rents in the ooze-covered floor come the heated water and gases. A tunnel has been driven along the former channel of the stream so that the cave can be entered with ease. The water in the cave is about 90° F., and the sulphur content is high. There is a natural basin formed beside the cave and into it some of the water enters from the spring within the cave.

During the summer of 1912 another cave was discovered about 50 feet above the lower hot spring. There is only one small opening into the side of the cavern. This cavern is irregular in shape, from 10 to 20 feet in diameter; the walls of the cave are coated with sulphur and calcite crystals. This cave is in line with the three springs and is of similar origin although it does not contain any active spring.

All of these springs are situated in the Intermediate limestone of Devonian age.

There are other springs of warm water coming from the rock at the base of the Vermilion Lake range on the north side of Bow valley. Sulphur water was also detected in several small streamlets coming from the rocks along the sides of the largest valley which comes from the south end of the Sawback range, 4 miles west of Banff station.

There are cold springs in several localities throughout this section. On the valley to the west side of Copper mountain a chalybeate spring occurs. There is a thick coating of yellow ochre on the rocks about this spring; this iron hydroxide has been deposited from the water. There are other similar springs about 6 miles southwest of Vermilion pass where Tokumm creek or Prospector valley joins that of the Vermilion.

In the western part of the section in the lower Kicking Horse canyon there are two strong calcareous springs situated on the line of railway about 4 miles east of Golden. The water from one of these springs has been tested by McIntosh and Boyle in the McGill laboratories and found to be radio-active. The water from the other springs has not yet been tested for radioactivity

General Geology.

In this section across the Rocky mountains between the Cascade basin and Golden, all the geological periods from the Pre-Cambrian to the Cretaceous inclusive are represented, with the exception of the Triassic which is absent in this particular area. A part of the section was given in the Summary Report for 1911, page 178, but will be repeated here with certain modifications, and the remainder of the section will be tabulated. There is a complete section of the Cambrian formations with lower and upper contacts well exposed. The contact between the Silurian and Devonian formations is not exposed in this section.

The igneous rocks have been discussed in the Summary Report for 1910, page 139.

Table of Formations

System.	Formation.	Approx. thickness in feet.	Lithology.
Recent and Pleistocene	Fluviatile..	....	Gravel, sand.
	Lacustrine.	....	Gravel, sand, clay, silt, and conglomerate.
	Glacial..	....	Till.
	Erosion Surface		
Post Cretaceous?	Igneous rock..............	....	Nephelite syenite, ijolite, urtite, jacupirangite, etc.
Cretaceous	Upper Ribboned sandstone...	550+	Thin-bedded sandstone and shale with hard bands of sandstone.
	Kootenay coal measures.....	2,800+	Sandstone and shale with coal seams.
	Lower Ribboned sandstone..	1,000+	Thin-bedded brown sandstone and shale.
Jurassic	Fernie shale................	1,500+	Dark brown to black arenaceous shale; weathers into lenticular fragments.
Permian	Upper Banff shale...........	1,400+	Dark brown arenaceous shale; weathering reddish and yellowish.
Carboniferous	Rocky Mountain quartzite...	800	White to grey quartzite and siliceous limestone.
	Upper Banff limestone.......	2,300+	Thick-bedded dark grey limestones with numerous thin cherty layers underlain by thin-bedded limestone and shale; weathering grey.
	Lower Banff shale..........	1,200	Black to dark grey shale, argillaceous and calcareous; weathering light brown.
	Lower Banff limestone.......	1,500+	Thick-bedded grey limestones with numerous dolomitic segregations.

System.	Formation.	Approx. thickness in feet.	Lithology.
Devonian	Intermediate limestone......	1,800+	Thin-bedded limestones, with alternating more massive layers of grey dolomitic and siliceous limestone.
Devonian (?)	Sawback limestone..........	3,700+	Thin-bedded limestone interbedded with less resistant layers and brownish and yellowish shale.
	Contact relations not known		
Silurian	Halysites beds..............	1,850+	Dolomites and quartzites weathering light grey to white, with shale interbedded.
Ordovician	Graptolite shales............	1,700+	Black and brown fissile shales.
	Goodsir shale...............	6,040+	Cherts, cherty and dolomitic limestones, siliceous and calcareous slates and shales.
Upper Cambrian	Ottertail limestone..........	1,725+	Massive blue limestones with cherty and shaly bands.
	Chancellor.................	4,500+	Thinly laminated grey argillaceous and calcareous meta-argillites and shales; weathering reddish, yellowish, and fawn; underlain by highly sheared grey shales, slates, argillites, and phyllites in Ottertail valley.
	Sherbrooke.................	1,375	Thin-bedded oölitic, arenaceous or dolomitic limestones.
	Paget.....................	360+	Massive bluish grey limestones, with oölitic bands of dolomitic limestone.
	Bosworth.................	1,855+	Massive grey arenaceous and dolomitic limestone; weathering yellowish buff; interbedded with greenish siliceous shale; weathering, red, yellow, and purple.
Middle Cambrian	Eldon....................	2,728	Massive bedded arenaceous limestones forming cliffs and castellated crags.
	Stephen..................	640	Thin-bedded limestone, and shale; includes '*Ogygopsis* shale' in Mt. Stephen and 'Burgess Shale' in Mt. Field.
	Cathedral.................	1,595	Thin-bedded arenaceous and dolomitic limestones.
Lower Cambrian	Mt. Whyte................	390	Siliceous shale, sandstone, and thin bedded limestone.
	St. Piran..................	2,705	Ferruginous quartzitic sandstone.
	Lake Louise................	105	Compact, greyish siliceous shale.
	Fairview..................	600+	Ferruginous quartzitic sandstone. Local basal conglomerate and coarse-grained sandstone.
	Conformable in some places		
Pre-Cambrian	Hector....................	4,590+	Grey, green, and purple siliceous shale with conglomerate interbedded.
Base not exposed.	Corral Creek...............	1,320+	Quartzitic and coarse-grained sandstone with shale interbedded.

Total thickness 52,628+ feet.

Résumé of Section.

Cretaceous	4,350+feet.
Jurassic	1,500+ "
Permian	1,400+ "
Carboniferous	5,800+ "
Devonian	1,800+ "
Devonian (?)	3,700+ "
Silurian	1,850+ "
Ordovician	7,740+ "
Upper Cambrian	9,815+ "
Middle Cambrian	4,963 "
Lower Cambrian	3,800+ "
Pre-Cambrian	5,910+ "
Total	52,628+feet.

DESCRIPTION OF FORMATIONS.

Pre-Cambrian.

The beds placed in the Pre-Cambrian include all those below the definitely determined Olenellus zone of the Lower Cambrian. This series, which Walcott [1] defined as older than the Cambrian, was grouped by McConnell [2] as part of the Bow River series.

The distribution of the rocks in this system is confined largely to the lower slopes and to the floor of the Bow River valley. The exposures of these rocks form a band 3 to 6 miles wide, which extends from Hector lake to Castle Mountain station, where it is cut off by a fault. On the north side of the valley, the upper contact remains close to the base of the Castle Mountain range. It curves to the east around the base of Mount Hector and forms a bay, which includes a large part of the valleys of Pipestone river, Corral creek, and the west side of Baker creek. At the head of Corral creek the Cambrian beds cap the mountains and appear as an island surrounded by Pre-Cambrian rocks.

On the south side of the Bow valley the upper contact lies between 6,500 and 7,000 feet above sea-level. At Storm mountain, 6 miles southwest of Castle mountain, this band of rock curves to the south, thus following the eastern base of the cliff—forming Lower Cambrian quartzites in the Bow range.

The uppermost beds, the Hector formation, consist of grey, purplish, and greenish shale, interbedded with bands of conglomerate. The shale weathers greenish, purplish green, and brown. Below these beds is a much darker series of sandstone and shale, some being almost black, with bands of arenaceous shale. The lowest beds exposed in this area are grey sandstone. These beds are especially well exposed in Corral creek northeast of Laggan, but are covered up on the south side of the Bow valley. Walcott has grouped these sandstone beds in the Corral Creek formation. The base of the Pre-Cambrian is not exposed in this district, and the lowest stratum seen outcrops 2 miles east of Laggan station; it is an arkose-like conglomerate made up of small pebbles and grains of quartz, and angular crystals of white and pink feldspar. The cement is made up of finer material of the same composition.

The best exposed section, which the author examined and measured in part, is to the east of Mount Ball, on the top of a ridge extending from the Bow range towards Copper mountain. This section is over 4,590 feet thick; there are about

[1] Walcott, C. D.: Pre-Cambrian Rocks of the Bow River Valley, Smithsonian Misc. Coll., vol. 53, No. 7, 1910, pp. 423–431.
[2] McConnell, R. G.: Annual Report Geol. Surv., Can., 1885, p. 29D.

750 feet of conglomerate and shale with thick bands of shale above and below. As there are no thick layers of sandstone in this section these beds would correspond to the Hector formation. The sandstone beds exposed in Corral creek and grouped in the Corral formation are over 1,320 feet thick. There are, therefore, over 5,900 feet of Pre-Cambrian strata exposed in the Bow valley.

From one bed of purple shale, 18 inches thick, outcropping on the eastern base of Storm mountain close to the ***Twin*** lakes, specimens were collected containing fossil remains of a brachiopod shell about one-eighth of an inch in diameter. These were shown to Dr. Walcott in the field, who concurred in the belief that they are fossils.

The contact between the Pre-Cambrian and the Cambrian beds is exposed in different parts of the area. One of the best exposures is in the ridge between Bath creek and Bow river. Here the contact is a conformable one, with the Lower Cambrian massive white quartzite lying directly upon the shale of the Pre-Cambrian. An unconformable contact is well exposed in Fort mountain, 4 miles northeast of Laggan. Walcott shows a photograph of this contact in his paper on these rocks [1].

Another unconformable contact is exposed at the eastern base of Storm mountain. The Lower Cambrian quartzites are dipping 35° S. 5° W., and the Pre-Cambrian shales dip 31° S., 55° W.

In some exposures there is a basal conglomerate on the Pre-Cambrian, which consists of large rounded pebbles of white quartz in a cement of quartz and feldspar. More frequently the basal rock is a coarse sandstone with rounded and angular grains of quartz and feldspar, 5 to 15 millimetres in diameter. Some of the quartz grains have a glossy, almost opalescent colour. It is some of these coarse-grained, basal sandstone beds that Walcott includes in his term 'basal conglomerate'.

Cambrian.

The Cambrian series is complete in this section. It has a total thickness of over 18,578 feet. These formations have all been described in the Summary Report for 1911. The relation between the Sherbrooke limestone as exposed on Mount Bosworth, and the Ottertail limestone in the Ottertail range is well shown in the Van Horne range northwest of Mount Hunter. The Chancellor red-weathering shales fill the gap between the two, are overlain by the massive bedded Ottertail limestone, and lie conformably upon the Sherbrooke, which is a more thinly-bedded limestone. The total thickness of the Chancellor formation is between 4,200 and 4,600 feet. This is thicker than in the section measured during the season of 1911 in the Ottertail valley. The highly sheared rocks between Ottertail river and Mount Dennis and Mount Odaray represent a phase of the Chancellor formation which has been intensely regionally metamorphosed.

Ordovician.

Beds of Ordovician age have not yet been found in the Bow range or in the various other ranges east of the continental watershed. The Goodsir formation caps Ottertail range, floors Beaverfoot valley, and occurs on both sides of the Beaverfoot range. The beds on the eastern side of the Columbia valley at Golden belong to this formation. The beds are largely shales, some of which are much more highly metamorphosed than others. There is a thickness of 6,040 feet measured in Mount Goodsir, but there is reason to believe that this formation is several hundred feet thicker. There is a gradual transition into the overlying

[1] Walcott, C. D., Smithsonian Misc. Coll. vol. 53, plate 46, fig. 2.

Graptolite shales, which occur as two infolded bands in the Beaverfoot range. The thickness of these beds varies, and the lower contact is ill-defined, but there are at least 1,700 feet of black fissile shales, many beds of which contain graptolites.

Silurian.

The Halysites beds include all the strata that can be definitely placed in this system. They consist mainly of dolomitic limestone and white quartzite. Both of these rocks weather white or very light grey. The thickness of this formation varies, because it is terminated above by a fault contact or an erosion surface. At the head of a valley directly southwest of Palliser, these beds are between 1,600 and 2,000 feet thick, but are thinner in the canyon close to the railway. The white quartzite is over 900 feet thick.

Some of the beds of dolomitic limestone are highly fossiliferous. The fossils recognized are *Favosites*, *Halysites*, *Zaphrentis*, and other corals, crinoids, certain brachiopods, and at least one gastropod. Other dolomitic beds contain irregular translucent nodules of flint. In many respects some of these beds closely resemble the Intermediate limestone of the Sawback range, which is Devonian in age.

This is the youngest formation exposed to the west of the Continental Divide in the Rocky mountains, and the uppermost limit is defined by a fault or by an erosion surface.

Devonian.

Intermediate Limestone.—This formation occurs in the Sawback, Vermilion Lake, and Cascade ranges in the eastern part of the section. It is repeated in these various ranges by normal faulting. This formation has a measured thickness of about 1,800 feet in the Sawback range. These beds form the base of Pilot mountain and Mount Bourgeau but are faulted off in Copper mountain, and in the eastern base of Castle mountain. It is in this formation that the thermal sulphur springs at Banff occur. The rock is rich in sulphur, probably from the decomposition of iron sulphide which it contains, so that it gives a strong odour of sulphide of hydrogen when struck with the hammer.

Certain horizons are very fossiliferous, *Zaphrentis* and brachiopods are the most abundant forms. Some of the beds in Fossil mountain at the headwaters of Baker creek and Red Deer river belong to this formation.

The upper limit of this formation is not clearly defined as it is transitional into the overlying Lower Banff limestone.

Sawback Limestone.—The Intermediate limestone is underlain by a conformable series of massive and thinly-bedded dolomitic limestones and shales which McConnell has placed in the Cambrian [1]. These latter beds form a wedge-shaped band in the Sawback range and lie between Mount Hole-in-the-Wall and Mount Edith, with a broader exposure along the north side of the Bow valley. Although they are very badly broken up here, it was possible to measure and estimate a thickness of about 3,700 feet, but the actual thickness is believed to be much greater. The eastern side of this band of rock is defined by a strike fault, which cuts across the beds in this formation at a small angle.

Fossils have not yet been found in this series. Since they differ lithologically from the Cambrian beds in Castle mountain, which is largely Middle Cambrian, and from the Cambrian in the Bow range and to the west, it is proposed to call these beds the ***Sawback*** formation. These beds are lithologically closely related to some of the Silurian beds in the Beaverfoot range.

[1] McConnell, R. G., Annual Report, Geol. Surv., Can., 1886, p. 28D.

Carboniferous.

Lower Banff Limestone[1].—This formation grades into the Intermediate limestone below, but is more sharply defined on the upper contact. The beds consist of massive-bedded grey limestone, which forms steep escarpments where exposed on the side of the mountain. This limestone forms the eastern cliffs in the Cascade mountains and also those in Mount Rundle. The steeper eastern slopes in Sulphur mountain are formed in the same formation. The vertically dipping beds form abrupt precipices about Mount Edith, and in other peaks on the west side of the valley of Fortymile creek. Some of the layers are fossiliferous, but the formation is characterized by numerous fossil-like dolomitic segregations. The thickness of this formation in Sawback range is 1,500 feet.

Lower Banff Shale.—These beds are sharply defined from the formations above and below, by their shaly character and their non-resistance to erosion. Where this formation crosses a ridge or intervening mountain, there is a deep depression or even a canyon formed. Thickness about 1,200 feet.

Upper Banff Limestone.—The top of the formation consists of thick layers of limestone interbedded with shaly limestone and numerous cherty lenses. The underlying beds are shaly. Alternating layers of shaly limestone and cherty shale are common. This feature helps to distinguish this formation from the shale below. Certain layers contain abundant corals and brachiopods. A measured section of this formation gave over 2,300 feet in thickness.

Rocky Mountain Quartzite.—The more gradual westward slopes of many of these ranges are capped by this white and grey quartzite. The formation has a thickness of about 800 feet in the Sawback range, but rapidly thickens towards the east, so that at Lake Minnewanka there are 1,600 feet of quartzite represented[2]. The fossils which this formation contains can most readily be found on the weathered surfaces of the rock.

These are the highest beds in the Carboniferous and according to the classification given by Shimer in the Lake Minnewanka section[3] the upper two formations are Pennsylvanian and the lower two are Mississippian in age.

Permian.

Upper Banff Shale.—This formation consists of a series of brown, calcareous and arenaceous shales, interbedded with thin layers of sandstone. All the beds weather readily and form a depression on the ridges through which they strike. It is difficult to get an accurate measurement of these beds, because they are frequently contorted and folded but there are over 1,400 feet represented in the section. Shimer[4] has on palæontological evidence placed this formation in the Permian.

Jurassic.

Fernie Shale.—This formation consists of black and dark brown siliceous shales very thinly laminated, which break up into small fragments on the weathered surface. The distribution of these beds is quite limited west of Banff. One small lens of shale occurs up the Spray valley about 8 miles southeast of Banff. There is a down-faulted block of shale exposed at Massive siding, 11 miles west of Banff. At this locality these beds form a transverse ridge between Castle and

[1] Since this report was written, Dr. H. W. Shimer has found that fossils recently collected from this limestone show it to be largely, if not wholly, of Devonian age.

[2] Shimer, H. W., Summary Report, Geol. Surv., Can., 1910, p. 148.

[3] *idem*, p. 147.

[4] Shimer, H. W., Lake Minnewanka Section, Summary Report, Geol. Surv., Can., 1910, p. 148.

Sawback ranges. This ridge has caused the lower part of Johnson creek to become deflected to the west. Ammonites were found in both of the localities mentioned. East of Banff the Fernie shale forms a band about 1,500 feet thick on the north side of the Cascade trough.

Another band of this formation was examined near Exshaw, 6 miles east of the Gap. The shales are exposed up the first valley, 1 mile east of this place, and 4 miles north of the railway. There are about 1,000 feet of shale exposed. The beds contain numerous ammonites. One layer of black shale contains several well-rounded clay concretions having the form of a slightly flattened sphere. One of these concretions has been procured for the museum at Banff. It weighs 233 pounds and shows horizontal stratification.

There is another layer of shale about 6 inches thick in the same formation that contains numerous bone fragments, probably reptilian, many of which are well preserved. Mr. L. M. Lambe informs me that this is the third locality in which vertebrate remains have been found in the Jurassic shales of the Rocky mountains. The other two localities, both of which have been examined by D. B. Dowling, are in Jurassic rocks at Sheep river, Alberta, and in the Fernie shale on the south fork of Oldman river, south of the Exshaw locality.

Triassic beds have not yet been determined within this portion of the Rocky mountains. Limited areas may occur in some of the ranges to the east, since strata, definitely determined as Triassic, have been found in the Brazeau mountains to the north.

Cretaceous.

The Cretaceous formations are exposed at the eastern base of Cascade mountain. The Upper Ribboned sandstone and the Kootenay are faulted off against the Devonian in Cascade mountain. The thickness of these formations, given in the table, has been measured by Dowling[1] in the Cascade basin.

The Kootenay contains the productive coal measures in which the mines at Bankhead and Canmore are situated.

Pleistocene.

In the lower canyon of the Kicking Horse river, gravel, sand, and till, formed by ponding in front of the ice, appear in distinct terraces at frequent intervals along the sides of the valley. Five distinct terraces are seen from the railway one mile east of Palliser. At the mouth of the canyon at Golden the gravel extends to an elevation of 3,100 feet above sea-level, or 500 feet above the Columbia river at this point. These deposits in the Columbia valley do not extend across the entire Beaverfoot range, but are absent from that part of the Kicking Horse valley across the central portion of the range.

River terraces are a distinct feature along the sides of the Bow valley and its tributaries. The deposits have a maximum height of about 700 feet above Bow river in some places. A 300-foot terrace is well marked in the upper part of the Bow valley in the vicinity of Laggan.

Structural Geology.

The various mountain ranges along this section have a general northwest and southeast trend, which corresponds to that of the Rocky Mountain system. The direction is about N. 60°W.

[1] Dowling, D. B., Cascade Coal Basin, Geol. Surv., Can., 1907, p. 8.

In the eastern part of the section the formations are dipping towards the southwest at angles up to 75 degrees, while in the western part of the section, between the Columbia and the Beaverfoot valleys, the beds have a corresponding dip to the northeast. The formations in Ottertail, Van Horne, Bow, and Castle Mountain ranges are flat-lying, gently undulating or dipping to the southwest.

The structure of the ranges on the east side of the continental watershed differs from that on the west slope of the Rocky mountains. Cascade, Vermilion Lake, and Sawback ranges, west of the Cascade trough, and the continuation of these ranges to the south of the Bow valley, represent separate fault blocks which have been tilted to a greater degree on the east side, so that the beds in each form a steep escarpment facing the east and a more gradual slope towards the west. This type of block faulting is absent throughout the western part of the section. With the exception of local crumbling and contortion of the softer shales there are no well defined folds exposed.

The strike fault is typically represented at several places along this section. The west side of Cascade trough is marked by a fault which follows along the base of the escarpments in Cascade mountain and Mount Rundle. Along this break the Devonian and Carboniferous formations are thrust over the Cretaceous.

The Vermilion Lake range is separated from Cascade range on the east, and from Sawback range on the west by faults which follow closely the strike of the softer shale formations.

The strike fault which has defined Johnson Creek valley, and which passes to the south of Fossil mountain, causes the Middle Cambrian rocks in Castle Mountain range to lie against those of Devonian and Carboniferous age in the Sawback range. There are many other smaller displacements in the formations, some of which do not follow the strike of the beds.

West of the divide the 'Stephen-Cathedral', 'Stephen-Dennis' faults and those in the Beaverfoot valley are the largest. These have been noted by the writer in the Summary Report for 1910, page 181. The formations in the Beaverfoot range are terminated by a strike fault along the eastern side of the Columbia valley. The displacement is very great but the exact dimensions could not be determined.

Economic Geology.

The Mount Stephen Mining Syndicate is now operating successfully the Monarch mine in Mount Stephen.[1]

A gravity concentrating mill has been in operation since it was completed in January, 1912. The mill has a capacity of eighty tons per day and is being operated near its maximum.

The ore is brought down from the mine by an aerial tram of the Leschen two-bucket type. The buckets hold about 1,500 pounds of ore. This tram is 1,000 feet in length and has a drop of 186 feet between terminals. The lower terminal is at the mill and the upper one connects with a tipple in the face of Mount Stephen. From the tipple there is a 300-foot tunnel, and an ore chute 475 feet in length with a 60 degree slope. From the upper end of the chute, which is beside the old trail that passes round the cliff 1,000 feet above the railway, a tunnel 211 feet in length and a raise of 185 feet at a 60 degree slope connect with a central point in the mine.[2]

The mill equipment consists of a Blake jaw crusher, 8 by 12 inches, one set of coarse rolls, one set of fine rolls crushing to $\frac{3}{16}$ inch, two sets of trommels, three Yeatman hydraulic classifiers, one four-compartment Hartz bull jig, two sets of three-compartment Hartz jigs, three Deister No. 2 tables, one Deister No. 3 slime

[1] Summary Report, Geol. Surv., Can., 1911, p. 182.
[2] Plan of Mine, Summary Report, Geol. Surv., Can., 1911, figure 7, p. 183.

table, one Wilfley table, one Baltic dewatering and settling tank, and two sets of belt elevators. There are also two bins for lead and two for zinc concentrates respectively.

The light for the mill, mine, and office is furnished by a 10 K.W. generator. An air compressor with a capacity of 250 cubic feet per minute furnishes the power for the mine. The air is delivered in the mine at 90 pounds per square inch.

The ore is chiefly galena and sphalerite, with a dolomitic and siliceous gangue. The separation of lead and zinc is remarkably clean; both of these concentrates are shipped. The lead concentrates run 67·6 per cent lead, and less than 9 per cent zinc. The lead ore contains an average of 5 ounces of silver to the ton, but the zinc does not contain any of this metal.

The zinc concentrates average 39 to 45 per cent zinc, 2 per cent lead, and 2 per cent lime. The loss in tailings is always less than 1 per cent. An average assay sample of tailings gave approximately 0·6 per cent lead and 0·9 per cent zinc. The Deister slime table saves galena which runs over 55 per cent lead. The mill feed averages 18 to 19 per cent lead and about the same in zinc.

The mill is handling 70 tons of ore per day. The average production during the summer of 1912 was one car (40 tons) of lead concentrates in four to five days. These concentrates are shipped to the Trail smelter. The zinc concentrates are being shipped to central United States.

The writer is grateful to Mr. J. A. Thomson, Managing Director, and to Messrs. J. J. Crothers, and C. A. MacKay, respectively, superintendents of mine and mill, for their courtesy and information when this examination was being made.

EXPLORATION BETWEEN LILLOOET AND CHILKO LAKE, BRITISH COLUMBIA.

(*A. M. Bateman*)

Introduction.

A month of the field season of 1912 was devoted to an exploratory trip from Lillooet on the Fraser river to Chilko lake, and in an exploration of Lake Chilko. The distance traversed, including the exploration of Lake Chilko, was about 225 miles.

No work has hitherto been done by the Geological Survey in this district and, with the exception of a sketch map compiled by the Provincial Mineralogist of British Columbia, no map exists of this portion of the country. The greater part of the route followed is known to only a few white men and Indians, while the mountainous country lying to the west of the route is wholly unexplored.

The purpose of the exploration was to gain a general knowledge of the geography of the country, a brief reconnaissance of the geology, and to roughly outline the Coast Range granitic batholith and ascertain, if possible, if the granite had produced along its contacts any mineralized area favourable for prospecting.

The geological examination was necessarily a hurried one and the excessively rainy weather that prevailed during this season retarded the work considerably. The area examined was confined to the vicinity of the route travelled, but numerous side trips were made to gain more extended information.

Supplies were obtained at Lillooet and a start was made from there along the Bridge River wagon road as far as Fivemile creek where the Chilcotin trail leaves the main road. This trail was followed past Pearson lakes and up the long steady climb to the first summit. A short distance below the summit the main trail was left and a short cut taken via Taylor and Eldorado creeks, thereby crossing the divide between Tyaughton and Gun creeks. The Chilcotin trail was again picked up beyond Eldorado creek and was followed over low flat summits as far as Spruce lake. From Spruce lake the trail led down a steep slope to the west branch of Tyaughton creek which was followed to its head-waters. The divide between Tyaughton creek and Big creek was then crossed. At this point the main Chilcotin trail, which continues on to Hanceville, was left and a more westerly trail was followed across the valley of Big creek and up the swampy valley of Glacier creek. At the head-waters of this creek the trail was followed over a glacier and into the head-waters of Iron creek, a tributary of Whitewater river. At the mouth of Iron creek we found an Indian hunting trail and followed it down the east side of Whitewater river and lake to the narrows of the lake. An alternative trail, which saves a day's travelling, but can be used only in late summer, leads from Big creek up Tyee Jimmie valley, crosses a divide into Foster valley and joins the Nemaia Valley trail at the narrows of Whitewater lake. At this point it was necessary to construct a raft and swim the horses across the narrows a distance of about 600 feet. On the west side of the lake we again followed a hunting trail used by the Chilcotin Indians, in a northerly direction to Queens lakes, a favourite fishing ground of the Indians. From here the trail led westward over Chilko pass and into Rainy valley. A low divide was crossed at the head of this valley and a steep descent was made into Nemaia valley, which was then followed down to the east side of Chilko lake.

Thirteen days were occupied in making the trip from Lillooet to Chilko lake. Pack horses were used for travelling and it was necessary to load them lightly on

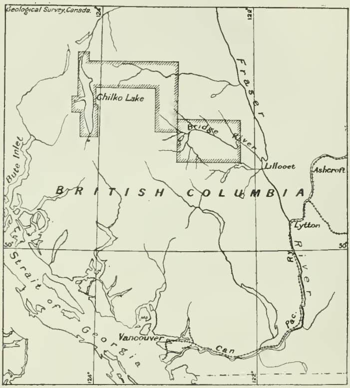

Fig. 6.—Index showing position of areas described.

account of the bad trails and steep climbing. For the exploration of Chilko lake, dug-out canoes were obtained from the Nemaia Valley Indians.

Summary and Conclusions.

The country traversed in this exploration trip lies between the eastern border of the Coast range and the Interior Plateau of British Columbia. The border of the Coast range is extremely irregular in outline and trends in a general northwesterly direction from Gun creek to the head of Chilko lake. The mountains are extremely rugged and range in elevation from 7,500 to 9,500 feet above sea-level. The higher parts are covered by large snow fields and contain many small glaciers. The Interior Plateau has a smooth rolling upland surface about 3,000 to 4,000 feet above sea-level and is sharply dissected by the streams. The western border of the plateau extends in a northwesterly direction from the head of Big creek to the foot of Chilko lake and is faced on the west by the foothills of the Coast range.

The geological formations range from the late Palæozoic to Recent. The rocks composing the part of the Coast range under consideration are light coloured granodiorites, of post-Lower Cretaceous and pre-Miocene age. The area covered by the batholith is much less than that indicated on previous geological maps.

The eastern boundary is extremely irregular and follows a line about N. 65° W. from Anderson lake to near the head of Chilko lake.

The Palæozoic rocks, which have been shown on previous geological maps, to underlie the country between Bridge river and Chilko lake, do not extend farther than 8 miles north of Bridge river. They consist of cherty quartzites, argillites, and altered volcanic rocks which are assigned to the Cache Creek rocks of Carboniferous age.

The Lower Cretaceous is represented in this area by an estimated thickness of 25,000 to 30,000 feet or more of clastic and volcanic rocks. They are divided into two series; an upper series composed largely of clastic rocks from 15,000 to 20,000 feet thick and a lower series composed of poryphyritic volcanic rocks and breccias not less than 10,000 feet thick. The lower series conformably underlies the fossiliferous upper series and may represent a downward extension of them into the Jurassic. The Cretaceous rocks form one continuous belt from Lillooet to Lake Chilko between the great body of the Coast Range intrusives on the west and the Tertiary rocks of the Interior Plateau on the east and cover the area represented as underlain by Palæozoic rocks on the Western Geological sheet of Canada.

The Tertiary is represented by basaltic and light coloured lavas, tuffs, and breccias. These underlie the Interior Plateau region and occur as erosion remnants capping the Cretaceous foothills of the Coast range.

Economically the region is not yet proved an important one. Some bog iron deposits have been located, but outside of this little prospecting has been done. There is a possibility of finding deposits similar to those of Eldorado creek in the country lying east of Tyaughton creek and south of Big creek.

General Character of the Country.

TOPOGRAPHY.

Three distinct topographic areas may be distinguished in the country covered by this trip, namely, the Red Mountain area, or the area underlain by Cretaceous rocks, the Interior Plateau area, and the Coast Range area. Each area presents an individual type of topography and is sharply marked off from the others.

The Red Mountain area is confined to the district underlaid by Lower Cretaceous rocks. It is sharply defined from the Interior Plateau to the north by Big creek and from the Coast range to the west by Tyaughton creek and extends as far east as the Fraser river.

The Red Mountain area is characterized by long, flat ridges and bare, rounded, gently sloping hills ranging in elevation from 7,000 to 8,300 feet above sea-level. Their smooth and rounded character is due to the rapidly weathering Cretaceous rocks which compose them. The hills are capped here and there by erosion remnants of flat-lying Tertiary volcanic rocks and exhibit grotesque forms of which Castle and Coffin mountains are examples. The hills are marked by a prevailing red colour and in summer are free from snow and accessible almost everywhere. The valleys are broad and steep sided, but are free from canyons. The valley bottoms and lower slopes are lightly forested and contain many open park-like areas covered by bunch grass.

In this area the Lower Cretaceous rocks are tilted at high angles and are unconformably overlain by the nearly horizontal Tertiary volcanics. Thus subsequent to the formation of the Lower Cretaceous rocks the Red Mountain area has been uplifted, tilted, and subjected to erosion and on this eroded surface the Tertiary volcanic rocks were extruded. This uplift which occured after the close of the Lower Cretaceous was more pronounced than any which affected

the younger formations. After the extrusion of the volcanic rocks the country was again elevated and slightly deformed, and the streams and their tributaries excavated wide valleys through the volcanic rocks and deep into the underlying Cretaceous. As erosion progressed the tributary creeks moved headwards and dissected the interstream areas so that the once continuous lava surface was reduced to a series of mountains topped by lava cappings which rest on highly tilted Lower Cretaceous rocks. From a high point it can be seen that the old eroded surface of the Cretaceous which underlies the capping of volcanic rocks, is extremely irregular and varies greatly in altitude. The gently tilted Tertiary volcanics show that a certain amount of deformation has occurred during the later uplifts but this deformation does not coincide with the irregularities of the Cretaceous surface beneath, nor is it so great. It thus appears that the erosion cycle which followed the elevation of the Lower Cretaceous rocks did not proceed far enough to produce a peneplained surface, but that the Tertiary volcanics were extruded on a surface of considerable topographic relief.

The traversed portion of the Interior Plateau is the most westerly part of the great Interior Plateau of British Columbia and forms a square cornered embayment which in its northern part abuts directly against the Coast range to the west but in its southern part is separated from the Coast range by the Red Mountain area. It is sharply defined from the Red Mountain area to the south by Big creek, and to the west is less sharply defined from the Coast range by a line which passes in a northwesterly direction from the head of Big creek to the lower end of Chilko lake.

The Interior Plateau is characterized by lack of relief and an open, gently rolling, sparsely forested surface which is dotted by small lakes and covered by glacial erratics. The general elevation of the plateau in this region is between 3,000 to 4,000 feet above sea-level. Low, dome-shaped hills rise above this general level to heights of 1,000 to 3,000 feet. The plateau surface is dissected by streams, which run in steep canyons 100 to 400 feet deep below the upland surface. From a high point the sharp incisions of the streams are lost to view and it appears to be one continuous, gently-rolling surface extending as far as the eye can see. The flat character of the present surface, in the vicinity of Big creek, is clearly due to the almost horizontally-lying Tertiary volcanic rocks which underlie it.

Along the border of the Interior Plateau the beds of volcanic rocks rise, from their almost horizontal position within the plateau proper, toward the Coast range at angles of from 15°—30°, showing that there has been a pronounced though gentle deformation of the plane of the plateau in this direction. To the eye the transition appears to be a gradual one as though brought about by gentle flexure. An examination of the rock structure, however, shows that much minor faulting has taken place in a line parallel to the axial uplift of the Coast range. It would appear, then, that the transition between the Interior Plateau and the Coast range has been brought about by both flexure and faulting due to uplift along the Coast Range axis. As this uplift involved the deformation of the Tertiary volcanics it follows that it is later in date than the extrusion of the volcanics which is provisionally referred to the Miocene. Thus, while in the Red Mountain area the region has been uplifted and the surface only slightly deformed, in the border zone of the Interior Plateau area nearer to the greater uplift along the axis of the Coast range, the region has been markedly flexed and faulted.

The Coast range is characterized by a type of topography peculiar to the granite and metamorphosed sediments which compose it. The area is mountainous and the peaks range in elevation from 7,500 to 9,500 feet above sea-level. The difference in elevation between the valley bottoms and the mountain peaks is from 4,000 to 7,000 feet. The individual peaks are steep and rugged, and rise

abruptly from the surrounding country in precipitous walls and cliffs of varied forms, due to the jointing planes of the rocks. The ridges are sharp and serrated and the valley walls are steep. All of the higher parts of the mountains are covered by snow and contain small glaciers, and west of the Whitewater river, snow fields, miles in extent, may be seen. The snow and ice have played an important part in steepening the peaks, sharpening the ridges, and excavating cirques. The higher portions of the mountains are free from vegetation, and where not covered by snow are seen to be composed of bare rock and are grey, solitary, and impressive in aspect.

Numerous wide valleys are a prominent feature of the part of the Coast range which was seen during the summer. They follow two well pronounced directions, one east and west and the other north and south in a direction nearly parallel to the main Coast range. The east-west valleys are broad, U-shaped, and floored with morainal material. The north-south valleys are broad, U-shaped, steep sided, and deep. They have been deepened and smoothed out by glaciers which occupied them during the Glacial period. These valleys are now occupied by the major streams, and the larger lakes such as Lake Chilko and Whitewater lake. Most of the tributary streams enter through hanging valleys.

The main axis of the Coast range trends in a northwest direction, but individual spurs project from the main range in a northerly direction and form an extremely irregular boundary.

The effects of glaciation are prominent in all these areas. In the Coast range they are exhibited by the rounded, straightened, and deepened characteristic U-shaped valleys, by the hanging valleys of the tributary streams, and by the glacial deposits which litter the floors and sides of the larger valleys. The present glaciers are still active, on a much smaller scale, in producing changes in the higher portions of the mountainous area. Glaciation over the plateau area is exhibited by the large glacial erratics scattered over the surface and the irregular unassorted deposits of till which give rise to a mound and basin topography.

CLIMATE AND AGRICULTURE

The country in the vicinity of Chilko lake enjoys a pleasant climate during the summer months, but a rigorous one during the winter months. Nemaia valley on the east side of Chilko lake is a particularly sheltered place, and in summer is warm and dry, and free from early frosts. In winter the temperature drops to 20° or 30° below zero, but scarcely any snow falls and horses and cattle are able to range out throughout the whole season. Outside of a few sheltered valleys the winter snowfall is heavy and does not disappear until July. West of Chilko lake, as the Coast Range divide is approached, the summer rainfall and winter snows are heavier and the vegetation becomes more luxuriant and dense, and approaches that characteristic of the coast regions.

Flat ground, suitable for agricultural purposes, is scarce, and the elevation, 4,000 feet and over above sea-level, is too high and the summers too short for the growth of farm products other than hay. In the valley of Queens lakes and Nemaia valley the bottoms and side hills are open and covered by bunch grass and wormwood, and are suitable for summer grazing grounds. In Nemaia valley a few of the hardier vegetables are raised, but no potatoes can be grown. Wild hay grows abundantly and is used by the Indians to feed their horses and cattle during the winter.

FLORA AND FAUNA

The trees that grow east of Chilko lake are black spruce (*Picea mariana*), white spruce (*P. canadensis*), balsam (*Abies subalpina*), white bark pine (*Pinus*

albicaulis), jack pine (*P. contorta*), Douglas fir, (*P. douglasii*), poplar (*Populus tremuloides*), cottonwood (*P. trichocarpa*) and alders (*Alnus*). The black and white spruce are the most plentiful and are found on all the hill slopes and valley bottoms. The jack pine generally occurs in places where the soil is sterile and the trees seldom attain a diameter of 14 inches. The white pine is not common and is to be found only in the higher altitudes. Except in the valley of Bridge river the Douglas fir is found only in Nemaia valley. The stumps attain 3 feet in diameter, but the trees are scarce. Poplar is a very abundant tree in all of the larger valleys, especially Nemaia valley, but seldom grows to more than 12 inches in diameter.

Wild potatoes, wild celery, and wild onions are found in the vicinity of Nemaia valley and are commonly used for food by the inhabitants, Bunch grass and wormwood cover the open sunny slopes and bottoms of Nemaia valley and the valley of Queens lakes.

Of the palatable berries the service berry or Saskatoon berry (*Amelanehior florida*) and the strawberry (*Fragaria sp.*) are the only ones that occur in this district.

West of Chilko lake the trees are similar to those of the east side, except for the absence of the Douglas fir and the presence of a few cedars. Undergrowth is more conspicuous, and ferns, devil's clubs (*Echinopanar horrida*), and alders are found along the streams.

There is a faunal as well as a floral distinction between the country east and west of Chilko lake. East of the lake, big-horn sheep, deer, goat, black and brown bear, and groundhogs are plentiful; while cougar, beaver, coyotes, and porcupine are less plentiful. West of Chilko lake big-horn sheep and coyotes are absent and deer are scarce, while goat, grizzly bear, and black and brown bear are very common. Blue grouse, willow grouse, and ptarmigan are found both east and west of Chilko lake.

In the vicinity of Big creek, bands of wild horses roam the country and are a source of trouble to travellers. These animals, shortly after they were brought into the country, escaped from domestication and have since been running wild and steadily increasing in numbers.

INHABITANTS

During the summer months the Chilcotin Indians make annual excursions into the country between Eldorado creek and Nemaia valley to harvest their winter's food supply of deer, groundhogs, and berries. In the winter months this region is not inhabitated.

Nemaia valley is inhabited by fourteen families of Chilcotin Indians and one white man. The Indians have built houses and fences, and fish, hunt, and cultivate the wild hay. They own altogether three hundred head of horses and twenty head of cattle. They are isolated in this valley, but maintain connexion with the town of Hanceville which lies on Chilcotin river about 25 miles west of the Fraser. These Indians originally belonged to the Stony Creek rancherie, but moved to this valley about twenty-five years ago and have occupied it steadily since then. They now resent the intrusion of the one white man who is trying to settle in the valley.

General Geology.

The following table provisionally summarizes the geological formations:—

Recent..............	Andesitic pumice.
Pleistocene...........	Glacial and stream deposits.
Tertiary (Miocene?)...	Volcanic rocks.
Post-Lower Cretaceous.	Granitic rocks.
Lower Cretaceous.....	Upper series—clastic and volcanic rocks.
	Lower series—volcanic and clastic rocks.
Carboniferous........	Cache Creek series—cherty quartzites, argillites, serpentine, and volcanics.

CARBONIFEROUS

The rocks of the Cache Creek series, referred to in the accompanying summary report on the geology of the Lillooet map-area, have been found to extend as far north as Eldorado creek, and in this locality outcrop along the divide between Eldorado creek and Taylor creek. They consist of thinly-banded cherty quartzites, argillites, dark green chloritic rocks, and impure serpentine.

They have undergone extreme alteration and are folded, faulted, and minutely crumpled. They are overlain unconformably by the Lower Cretaceous rocks which in places are eroded through and expose the underlying Cache Creek series. No specifically recognized fossils were found in the Cache Creek rocks and their age could only be relatively determined as older than the granitic rocks which intrude them. They are, however, lithologically and structurally similar to the rocks farther east, which were determined by Dawson on the basis of *Fusulina* to be of Carboniferous age.

LOWER CRETACEOUS

The rocks referred to this age are classified into an upper and lower series.

Lower Series.—The lower series consists of two classes of rocks, volcanic and sedimentary, of which the former are predominant. They occupy the lower part of the series and grade upwards into the sedimentary member. The total thickness of the series is estimated to be 10,000 feet or more.

The volcanic members are all andesitic in composition, usually rather basic varieties, and are characterized by prominent purple, green, and grey colours. They consist of porphyritic lavas of which the purple varieties are the most conspicuous; of breccias of the same colours, and of vari-coloured or white tuffs. The lavas are chiefly andesites and are the thickest and most widespread member of the igneous division. They are extremely compact and massive, and are composed of phenocrysts of feldspar and hornblende or augite or both, embedded in a fine grained groundmass which consists of feldspar, hornblende, augite, and glass. The breccias are mostly purple and light grey in colour and consist of angular fragments of purple and green andesite embedded in a light grey ash which in many places is also purple. The fragments in the breccia are mostly small, but in some places are 12 inches or more across. The breccias show a marked stratification and the individual beds are from 2 to 50 feet thick. The total thickness of the breccias is about 3,000 feet. The tuffs are light grey, water-laid ashes and are subordinate in amount. The sedimentary member at the top of the series consists of alternating thin beds of green and red tufaceous argillites, black slates, feldspathic sandstones, and conglomerates.

The lower series is widely distributed; it occurs in the vicinity of Whitewater river and lake and extends westward to Chilko lake where it outcrops along the east shore for a distance of 15 miles; it is also found along the west shore of the lake and appears to extend westward to Tatlayako lake.

The lower series represents a period of great vulcanism and differs in this respect from the upper series, which represents a period of dominant sediment-

ation. The volcanic rocks dip at high angles and conformably underlie the upper series, but may represent a downward extension of them into the Jurassic and thus be comparable to the volcanic materials extruded in Jurassic time in other parts of the western Cordillera. Although it is strongly suggested that they may be of Jurassic age sufficient evidence could not be found, however, to show that they belong to an older period or could be separated from the upper series. On this basis they are provisionnally classified with the Lower Cretaceous.

Upper Series.—This series consists of conglomerates, sandstones, slates, argillites, limestones, and volcanic rocks. It has an estimated thickness of 15,000 to 20,000 feet and probably more. The conglomerates are a massive, thick-bedded variety and have a total thickness of about 500 feet. They are composed of small, well rounded pebbles of cherty quartzite and volcanic rock which are embedded in a matrix of fine angular fragments of quartz, quartzite, and feldspar. The cherty pebbles are undoubtedly derived from the cherty quartzites of the underlying Cache Creek rocks.

Interbedded with the conglomerates are a few thin layers of sandstone and shale. Above the conglomerates are thick beds of coarse, greenish-grey feldspathic sandstone composed largely, of angular particles of quartz and feldspar. Above these again are dense, hard, black and grey slates with occasional sandy layers, and beds of andesitic volcanic rocks. The upper part of the series consists of a great thickness of alternating thin beds of dense, black slates and green feldspathic sandstones. A few beds of crystalline limestones occur with the slates. They are usually thin and squeezed into irregular masses. In some localities red, black, and sea-green argillites occur in the lower part of the series.

This series is highly folded and crumpled but to a much less extent than the Cache Creek rocks. The strata dip at high angles and the strike is in general parallel to the main structural trend of the Coast range or about N. 30° W.

The upper series occurs in the vicinity of Eldorado creek, extends in a westerly direction as far as Big creek, and underlies the country between Tyaughton creek and the Fraser river. It is also found in Nemaia valley and around the west arm and lower part of Chilko lake.

Some marine fossils of sufficient diagnostic value to determine the age of these rocks were collected from this series. Among those that have been identified are: *Aucella crassicollis* (Keyserling), *A. piochii* (Gabb), *A. pallasi* (Keyserling), *Aucella sp.*, *Belemnites impressus* (Gabb), *Belemnites sp.* and *Terebratula sp.* All of these fossils and especially the different species of the genus *Aucella* are diagnostic of the Comanchie or Lower Cretaceous.

These rocks are lithologically similar to and contain fossils that suggest the Shasta group of California and the Queen Charlotte Islands group of British Columbia. They are also similar to the Cretaceous rocks of the vicinity of Lillooet which Dawson has called the Queen Charlotte Islands group.

TERTIARY

The rocks referred to the Tertiary consist largely of volcanics but include a few thin beds of tuff and light coloured sandstone. The volcanic rocks are predominantly basic and consist of dense black basalts, green and black augite andesites; green, grey, and purple andesitic lavas, and minor amounts of trachyte and rhyolite. Many of the porphyrites are difficult to distinguish in the hand specimen from the porphyrites of the lower series of the Cretaceous. A few thin beds of tuffs are interbedded with the volcanic rocks. The basaltic rocks are usually massive and exhibit columnar jointing. The beds vary in thickness from 1 to 100 feet and dip at low angles to the north and south.

This series of volcanics rests unconformably on the eroded, upturned surface of the Cretaceous strata and is not cut by the granitic rocks that have intruded the Lower Cretaceous. The volcanics are, therefore, of post-Lower Cretaceous age and later than the granitic intrusives. No fossils were found in any of these rocks so that the age cannot be definitely determined. They are, however, lithologically similar to the volcanic rocks west of the Fraser river which Dawson mapped as Miocene. They are mainly confined to the area outlined as the Interior Plateau, but are also found as erosion remnants capping the mountains east of Gun creek and along the east side of Chilko lake, south of Nemaia valley.

PLEISTOCENE

The Pleistocene deposits are unconsolidated till and river gravels, which floor the larger valleys and are spread out over the surface of the Interior Plateau. The valley deposits consist of poorly assorted sands, gravels, and silts. The plateau deposits are unassorted boulders, gravels, and sands deposited by glaciers and spread out irregularly over the surface.

RECENT

White, pulverulent, scoriaceous, andesitic pumice, similar to that which is described in the accompanying summary report on the Lillooet map-area, extends north of Eldorado creek along the divide between Gun and Tyaughton creeks. This 'volcanic ash' or scoriae forms a superficial layer from 1 to 10 inches thick and overlies the most recent river deposits and the earlier vegetation. The material is finer grained than that farther south and the deposit thins out toward the north and west. It represents a recent outburst from some volcanic vent which probably lies in a southwest direction from Eldorado creek. A similar but unconnected deposit of recent scoriae occurs in the neighbourhood of the head-waters of the north fork of Bridge river. It is thus probable that this material was ejected simultaneously from more than one volcanic vent. No vent has yet been discovered.

GRANITE ROCKS

The granitic rocks encountered in this area are a part of the Coast Range Intrusives. They are mostly coarse grained, light grey in colour, and are essentially granodiorites. The component minerals are plagioclase, orthoclase, quartz, biotite, and hornblende. The rock is fresh and massive and does not exhibit any gneissic structure. The granodiorite of the upper end of Chilko lake contains many patches of darker rock which in places appear to be segregations of basic minerals but are more suggestive of included and altered fragments of a basic igneous rock somewhat similar to the overlying augite andesites of the Lower Cretaceous formations. These inclusions vary in size from 3 inches to 3 feet. Sills of granodiorite porphyry some of them 1,000 feet in width intrude the Lower Cretaceous strata. They are usually dark grey in colour and are composed of phenocrysts of feldspar and hornblende embedded in a fine granular groundmass of feldspar, quartz, hornblende, and biotite. These sills are directly connected with the Coast Range Intrusives and are apophyses from them. Along the contacts of these sills the invaded rock is usually metamorphosed and silicified.

The granitic rocks are to be found to the west of Whitewater river and in the country lying between the head of Whitewater lake and the head of Chilko lake, and extend in a northwest direction from Chilko lake toward Tatlayako lake. The eastern boundary of the area of granitic rocks is extremely irregular in outline

but follows a general westerly trend from the mouth of Eldorado creek to the head of the west arm of Chilko lake. The age of the granitic rocks of this part of the Coast Range batholith is considered to be post-Lower Cretaceous and pre-Miocene. They intrude the Lower Cretaceous but do not cut the Tertiary rocks, which are considered to be of Miocene age. No pebbles of granitic rocks could be found in the extensive conglomerates of the Lower Cretaceous series.

Economic Geology.

The only mineral in the area covered by the exploration trip that may prove to be of economic importance is the bog iron ore of Iron creek and Whitewater river.

In the area lying east of Tyaughton creek and south of Big creek are found the same rocks intruded by dykes similar to those which contain the arsenical gold deposits in the vicinity of Eldorado creek, and it is not unlikely that similar gold deposits may occur in this area. If the deposits of Eldorado creek, which are described in the summary report on the Lillooet map-area, prove with further development work to be of economic importance, then the area in the vicinity of Tyaughton and Big creeks would be a favourable place to prospect. Similar rocks are also found about the lower end of Chilko lake, but the intrusive granitic dykes are less prominent. A few small seams of stibnite, the sulphide of antimony, were found on the west side of Chilko lake about 5 miles below Nemaia valley. The stringers themselves are of no commercial importance but indicate that mineralization has taken place in this vicinity. No area was seen in the vicinity of upper Whitewater lake or upper Chilko lake which could be recommended as a favourable place for prospecting. The gravels from many of the streams were tested for gold and other minerals of economic importance which might lie within their drainage, but none were found. Nothing whatever is known of the economic possibilities of the area lying about the head of Whitewater lake. The possibility of the occurrence of coal in the Lower Cretaceous rocks was borne in mind but no indication of any could be seen.

IRON ORE

Deposits of iron ore have been located on the west side of Whitewater river and along Iron creek. Only those of Iron creek were examined. These claims were staked in 1911 and practically no work has been done upon them. They cover the valley of Iron creek, an easterly tributary of Whitewater river, and are located at an elevation of 6,400 feet above sea-level.

The rocks of this section belong to the volcanic series of Tertiary age. They consist of basalts, augite andesites, andesites, rhyolites and andesitic tuffs, breccias, and agglomerates. They occur in well pronounced beds and dip to the north at an angle of 20°.

The deposits consist of bog iron ore of a yellowish-brown colour. The ore occurs as a hard compact limonite, as a cement in the consolidated talus, and in a light porous state replacing moss and leaves. The deposits are from 2 inches to 5 feet thick and cover scattered patches of the bottom and sides of the valley. They are irregular in extent and thickness and while 5 feet of solid limonite may be found in one place, in another spot a few feet away there may be only a superficial stain. These patches and intervening spaces of stained rock cover the valley for a width of 1,000 feet and a length of about a mile.

The bog iron is of local origin and is derived from disseminated pyrite contained in a bed of rhyolite which outcrops on the adjacent hillside. By means of surface waters it was taken into solution and deposited as bog iron in the swampy bottom of the valley.

These bog iron deposits cover a considerable area but are very scattered and of no great thickness, and this taken into consideration with the low percentage of iron in bog ore, the altitude of the deposits, and the distance from transportation, would place their development beyond the reach of present commercial possibilities.

Similar deposits of bog iron occur west of Whitewater river, in Schwartz valley and around the head-waters of Gun creek.

LILLOOET MAP-AREA, BRITISH COLUMBIA

(A. M. Bateman)

Introduction.

During the field season of 1912 geological work pertaining to the economic resources of the Lillooet map-area was carried on under the direction of Mr. Charles Camsell.

The district lies immediately west of the Fraser river between latitude 50° 45′ and 51° 15′ and includes a portion of the drainage basin of Bridge river. Access to the district is gained by means of a wagon road and trails starting from the town of Lillooet which lies on the eastern border of the Lillooet map-area. Lillooet is reached by stage from either Ashcroft or Lytton on the main line of the Canadian Pacific railway.

A location survey of the Pacific Great Eastern railway is at present being run along Anderson and Seton Lake valley past the town of Lillooet, and it is expected that railway construction will be started in the near future.

The discovery of placer gold in the Fraser river at Lillooet in 1859 and later in Cayoosh creek, Bridge river, and some of its tributaries, awakened the first mining interest in the district. At present placer mining is attempted in only a few localities. The presence of placer gold in the south fork of Bridge river and Cadwallader creek led to the discovery in 1897 of the gold quartz veins in the Cadwallader Creek section, and later, of other veins in the vicinity of McGillivray creek, Bridge river, Shulaps mountain, Tyaughton and Gun creeks.

With the exception of a brief reconnaissance trip by Mr. Charles Camsell in 1911[1], no geological work has been carried on in this district by the Geological Survey, and the only published information is that contained in the report of the Provincial Mineralogist of British Columbia who made a short visit to some of the properties in the autumn of 1910. A topographic map is at present being constructed by W. E. Lawson of the Topographical Division of the Geological Survey to include an area of about 850 square miles, the north boundary of which will pass through Eldorado creek and the south boundary of which will cross Cadwallader creek in the vicinity of Hawthorne creek, or from latitude 50° 45′ to 50° 15′ north and from longitude 122° 30′ to 123° west.

C. E. Cairnes acted as a diligent assistant during the field season. Thanks are due to the mine managers, prospectors, and residents of the district for their hospitality and assistance during the summer.

Summary and Conclusions.

The area covered by the season's work lies in the eastern border region of the Coast Range mountains and merges on the east and north into the Interior Plateau of British Columbia. The mountains are high and rugged and the difference in elevation between the valleys and the highest mountain peaks is over 7,000 feet. The rocks underlying the area consist of immense thicknesses of highly altered sedimentary and volcanic rocks correlated with the Cache Creek series of Carboniferous age, and of part of a great series of clastic rocks belonging

[1] See Summary Report, Geol. Surv., Can., for 1911, pp. 111–115.

to the Lower Cretaceous. Diorite and granitic rocks occur as outliers of the Coast Range granitic batholith. The granitic rocks are of post-Carboniferous and, in part, of post-Lower Cretaceous age.

Economically, the region is important for the gold-quartz and gold placer deposits. The placer deposits have been mined extensively in the past, but the work has now almost ceased. The gold-quartz deposits are scattered over a number of localities in the district, but the Cadwallader Creek section is the only one in which mining is being carried on at present. The ore deposits of this section consist of banded fissure veins in augite-diorite and the workable deposits so far found are dependent upon the diorite and confined entirely to it. It is not improbable that other veins may be discovered in the diorite by detailed prospecting. The veins are small but continuous and persistent. The depth so far attained is not great, but since the veins occur in a homogeneous plutonic rock there is no reason to suppose that they may not extend to a considerably greater depth. The gold content of the veins is sufficiently high to justify mining and extraction of the ore on a commercial basis. The veins, however, are too small and too few in number to warrant extensive operations.

General Character of District.

TOPOGRAPHY

The district lies on the eastern border of the Coast Range mountains and faces the Interior Plateau of British Columbia on the east and north, the two being separated at this point by the Fraser river. Immediately west of the Fraser river the hills are rounded, with elevations of about 6,000 feet but rise within the Lillooet map-area to steep, rugged, snow capped mountains which increase beyond the western border of the map-area to a confused mass of high, jagged, snow covered peaks and ridges with intervening valleys bordered by precipitous slopes in which many small glaciers are nestled. The ruggedness is in part due to these glaciers, which have excavated cirques on opposite sides of ridges and reduced the divides to narrow ridges and the summits to sharp peaks.

The ruggedness of these mountains as compared to the Interior Plateau to the east and north has been further intensified by the older and harder rocks which comprise them and which differ in this respect from the softer weathering Cretaceous rocks of the adjacent portion of the Interior Plateau. The peaks range in elevation from 7,500 feet to 9,200 feet, and the valley of Bridge river from 1,900 to 2,150 feet, so that the greatest vertical relief is over 7,000 feet.

The main range of the Coast mountains in this portion of British Columbia trends in a northwest direction, but individual spurs branch out from the main body in a northerly direction. One such spur, locally known as Shulaps mountain, stands out above the surrounding country. It crosses above the canyon of Bridge river and appears to gradually merge or smooth out into the plateau country to the north.

From a high point the mountain peaks of the Coast range appear to conform roughly to one general level with only a few isolated peaks rising above it. This general uniformity of peaks is due more probably to the excessive erosion of the snowy regions wearing down the higher portions to a level where it is retarded by vegetation, than to a previous peneplanation.

Bridge river and its larger tributaries, the North and South Forks, Cadwallader, Gun, and Tyaughton creeks, form the main drainage of the district and this water reaches the Fraser at a point about 5 miles above Lillooet. A smaller area to the south is drained into the Fraser by way of Anderson lake, Seton lake,

and Cayoosh creek. The tributaries of Bridge river enter with steep gradients and flow through precipitous and narrow valleys and canyons. For 25 miles above its mouth Bridge river flows swiftly through a steep canyon. In the upper 10 miles of this canyon the walls rise almost vertically from the river for about 2,500 feet, but above the canyon the valley broadens and the river meanders over a wide, flat bottomed, swampy valley containing many small lagoons and river cut-offs. This wide, silt-covered portion of the valley extends upstream to beyond the Wayside mine, a distance of about 30 miles, where it again changes to a narrow valley with a steep profile broken by falls. Above this, the current again becomes sluggish and the valley broad and flat, containing many swamps and ox-bow lakes, remnants of previous river meanders. Where the Cadwallader valley joins with that of the South Fork there is a broad flattish bench which extends from the junction of these two streams to where the South Fork enters Bridge river. Into this bench the South Fork is sharply incised and flows through a steep narrow canyon. The formation of the bench is considered to be due to the combined action of glaciers from the Cadwallader, South Fork of Cadwallader, and South Fork of Bridge River valleys which at their point of coalescence, during the Glacial period, widened and deepened a previously formed river valley.

A similar bench occurs along the north side of Bridge river about 800 feet above the present stream. It is a remnant of what was in recent geological time the valley bottom of Bridge river, and is now occupied by a chain of lakes extending from the upper Gun lake to below Tyaughton lake. Gun creek also flows through a steep notch sharply incised into this old valley bottom or bench and exposes a section of well rounded river gravels which must have been laid down when Bridge river occupied this old valley.

CLIMATE AND AGRICULTURE

The climatic conditions of the district are in general similar to those of the western interior of British Columbia. The summer months are pleasantly warm without being too hot. Rainfall is light and dew is almost unknown. During the winters the cold is not excessive and the snowfall is not heavy. Excessive snow, however, accumulates in the higher parts. In Lillooet the snowfall is not sufficient for continuous sleighing, and 5° below zero is considered cold, but snowfall and lower temperatures progressively increase westward to the main Coast range in response to increased elevation. The rivers and creeks are generally free of ice in April, and Anderson and Seton lakes seldom freeze over. Mining operations on the surface begin before May and continue until November.

The land in the vicinity of Lillooet is well adapted for agricultural purposes and excellent vegetables and farm products are grown by the aid of irrigation. Many varieties of fruits, particularly apples, peaches, pears, plums, and berries are successfully raised and, in size and flavour, equal those of other fruit districts of British Columbia. Along the valley of Bridge river agricultural land is not plentiful, but at elevation not exceeding 2,500 feet good farm products, vegetables, and the hardier fruits are successfully grown.

FLORA AND FAUNA

The limit of timber growth in this district varies in different valleys from altitudes of 6,000 to 7,000 feet. The northward facing slopes are always heavily forested, while the southward facing slopes are mostly semi-open and, below altitudes of 3,000 feet, are well timbered by fir trees with stumps attaining 4 feet in diameter. The main varieties of trees are Douglas fir (*Pseudotsuga mucronata*), black spruce (*Picea mariana*), white spruce (*P. canadensis*), yellow pine (*Pinus*

ponderosa), white pine (*P. albicaulis*), black pine or jack pine (*P. contorta*), balsam fir (*Abies subalpina*), western larch (*Larix occidentalis*), cottonwood (*Populus trichocarpa*), aspen or quaking poplar (*P. tremuloides*), willow and some cedar (*Thuya gigantea*). The Douglas fir is the most valuable. It is usually confined to the south slopes of the hills below 3,000 to 2,000 feet altitude. Above this it is replaced by black spruce, balsam, and larch. The black spruce is the most plentiful of the trees, occurring in dense forests chiefly on the north slopes and in the valley bottoms. It usually grows straight and clear and stumps measure 2½ feet in diameter. The jack pine is of small size but very abundant along the gravelly river benches, and in the district covered by lava ash often forms impenetrable growths of trees not exceeding 6 inches in diameter. The cottonwood and poplar are usually confined to the valley bottoms and lower slopes. Of the wild fruits, the Saskatoon berry or service berry (*Amelanchior florida*) is the most plentiful and may be found on all the sunny slopes. The Chilcotin Indians make annual excursions into this country to collect and dry these berries for their winter's food. Other palatable berries are red currants (*Ribes rubrum*), strawberries (*Fragaria, species*), raspberries (*Rubus, species*), gooseberries (*Ribes, species*), and high bush cranberries (*Viburnum pauciflorum*).

Deer, goat, and sheep abound in the hills, and black, brown, and grizzly bears are plentiful in some localities. Cougars, wolverine, beaver, groundhog, and porcupine are not uncommon. Blue grouse, willow grouse, spruce partridges, and ptarmigan are also to be found. Nearly all the streams and lakes are well stocked with fish and offer good sport to the fisherman.

The diversity and abundance of the game in this district, particularly of the grizzly bear and bighorn sheep, make it one of the most popular districts in Canada for the big game hunters.

General Geology.

The following provisional table gives the geological formations of the district.

Recent	Volcanic scoriae. Stream deposits.
Pleistocene	Stream deposits. Glacial deposits.
Tertiary	Volcanic breccias, tuffs and lavas, sandstone, conglomerate and shale.
Lower Cretaceous	Conglomerate, sandstone, slate, limestone, and andesitic volcanic rocks.
Carboniferous	Cache Creek series—cherty quartzites, argillites, sandstone, limestone, serpentine and volcanic rocks.
Plutonic rocks	
Post-Lower Cretaceous	Granitic rocks.
Jurassic?	Augite-diorite.

CARBONIFEROUS

Rocks referable to the Cache Creek series comprise the oldest formations in the district. They consist of the series of much gnarled and folded, dark cherty quartzites occurring in bands of one-half inch or more in thickness, each narrow band separated from the other by thin layers of argillite; of massive grey and red quartzites and black and red argillites; of black conglomerates, grey sandstones, and dark fissile slates, sometimes carbonaceous. Intercalated with these are a few thin beds of crystalline limestone. The conglomerates, sandstones, and slates are less fractured and altered and have a younger appearance than the

cherty quartzites, but apparently are structurally conformable with them. They may possibly represent a later series of rocks, but for the present are correlated with the Cache Creek series. The Cache Creek series also includes great thicknesses of volcanic rocks. They consist of andesitic tuffs and breccias, light green chloritic rocks, vesicular and sheared basaltic rocks, agglomerates and serpentine. This formation has a general northwest strike and vertical or highly inclined dips to the northeast and southwest. The rocks have been faulted, and folded to such an extent that stratigraphic sequences and thicknesses could not be obtained. They are minutely crumpled and mashed and intersected by small quartz veinlets.

Except where intruded by igneous bodies this series occupies the greater part of the area included in the Lillooet map area. They extend along Bridge river, Cadwallader creek, Anderson and Seton lakes, and probably occupy the greater portion of the mountainous country between these places. North of Bridge river they have been found to extend as far as Eldorado creek.

No recognizable fossils were found in these rocks and their age could only be relatively determined as older than the diorite and granite which intrude them. Lithologically and structurally they are identical with the rocks farther to the east, described by Dawson as the Cache Creek series, which were found by him to contain *Fusulina* and to be of Carboniferous age. These rocks are considered to be a continuation of the same series. While Triassic and Jurassic rocks occur north and south of this area and may possibly be a part of what is included under the Cache Creek series, none have yet been recognized.

LOWER CRETACEOUS

The Lower Cretaceous rocks outcrop in the vicinity of Eldorado creek and occupy a narrow area along the northern part of the Lillooet map-area. They consist of conglomerate, sandstone, quartzite, slate, limestone, and andesitic volcanic rocks. The series is highly folded and has undergone considerable minor crumpling. The general strike is parallel to the Coast Range axis or about N. 35° W. and their dips range from 45° to 90° in southeast and northwest directions. They are a part of the great series of rocks that extend in a northwest direction beyond Lake Chilko. The aggregate thickness is not less than 15,000—20,000 feet and probably more. In the Eldorado Creek locality they rest unconformably on the eroded Cache Creek rocks. The conglomerates are a massive, thick-bedded variety and have a total thickness of about 500 feet. They are made up of small, well rounded pebbles composed chiefly of cherty quartzite and andesite embedded in a matrix of fine angular fragments, of quartz and feldspar. Above the conglomerates are indurated, coarse greenish-grey sandstones composed of angular particles of quartz and feldspar.

Above these again are massive, dense, hard, black and grey argillites with sandy layers, and some interbedded volcanic rocks. The upper part of the series consists of a great thickness of alternating thin beds of black slates and grey sandstones and a few thin beds of limestones.

In a few of the beds, in restricted places, some marine fossils were found of sufficent diagnostic value to determine the age of the rocks as Lower Cretaceous or Comanchie. The identification of the fossils was corroborated by Dr. T. W. Stanton of the National Museum at Washington.

The fossils collected are:—

Aucella crassicollis (Keyserling).
Aucella pallasi (Keyserling).

Aucella piochii (Gabb).
Aucella sp.
Belemnites impressus (Gabb).
Belemnites sp.
Terebratula sp.
Terebratuloid.
Gasteropods sp.
Hexacorolla, either *Thamnastraea* (?) or *Thecosmilia* (?). Of these the genus *Aucella* is the most characteristic and diagnostic and the species *Aucella crassicollis* is the most abundant.

The fauna of the Lower Cretaceous rocks in the Lillooet map-area is essentially similar to that of the Queen Charlotte Islands group and to the Knoxville member of the Shasta group of California and Oregon, and may be correlated with them and with the formations in southern and central British Columbia and Alaska which contain the widespread boreal *Aucella* fauna.

The recently discovered arsenical gold prospects of the Eldorado Creek district are associated with dykes intruding this series.

TERTIARY

A small group of rocks referable to the Tertiary occurs in the vicinity of Jones's ranch on the northeast side of Bridge river. These rocks consist of soft-weathering shales, sandstones, and conglomerates with some andesitic tuffs and breccias. A few thin seams of lignite coal occur in them. The rocks unconformably overlie the Cache Creek series and have low dips to the north and strike in an easterly direction.

PLEISTOCENE

Great thicknesses of well worn but poorly-assorted river gravels were laid down along the Bridge River valley and other river valleys at the close of the Glacial epoch. Along the valley of Cadwallader creek, small areas of glacial clay are found underlying the gravels.

RECENT

The recent stream deposits consist of gravels, sands, and silts. They floor the larger valleys and are in part a rewashing of the Glacial material. These gravels are of economic importance because of their placer gold content.

A recent deposit of white andesitic pumice is of special geological interest. This pumice, or volcanic ash, is found in the valley bottoms of the upper Bridge river and its tributaries, on the hill slopes and on many of the mountain summits. It is a white, pulverulent, scoriaceous, material and is so light and porous that it floats on water. It varies in texture from a fine powder to fragments of 2 inches or more in diameter. The thickest deposit seen was in the vicinity of the South Fork where one section measured 22 inches. It is estimated to cover an area of at least 1,500 square miles and forms a superficial layer overlying even the most recent river gravels. It supports but little vegetation and its light and pulverulent nature renders walking on it very difficult.

It is evidently the result of a recent outburst from some volcanic vent which probably lies between the head-waters of Bridge and Lillooet rivers and is probably connected with the line of hot springs which extend from the Lillooet river to Harrison lake.

PLUTONIC ROCKS

Augite Diorite

The typical augite diorite of the region is a dark coloured, medium-grained plutonic rock consisting essentially of hornblende and a light coloured feldspar. It is usually shattered and traversed by small interlacing veinlets of quartz. Along the contacts it takes on a greenish hue due to included fragments of the invaded rock. It intrudes the Cache Creek series and is, therefore, of post-Carboniferous age. No contacts between the augite-diorite and rocks younger than the Cache Creek series were seen.

In appearance it is a much more fractured and altered rock than the granite of this region. The augite-diorite is probably connected with the Coast Range granitic batholith and was intruded contemporaneously with the earlier granites which are usually referred to the Jurassic.

The extent of the diorite is of economic importance as the principal gold deposits of the region are directly associated with, and dependent upon it. It occurs as small, irregular, stock-like masses elongated in a northwesterly direction. The known outcrops of this rock are few, the most important being the one in which the Lorne, Coronation, and Pioneer mines are located. This extends along the north side of Cadwallader creek from a short distance above the Pioneer mine to below the Lorne. Its maximum width is about 3,000 feet. What is probably an extension of this belt occurs on the north side of Bridge river in the vicinity of the Wayside mine. The eastern contact of this diorite follows the draw above the Wayside cabin. Another similar diorite belt separated from the above by a narrow band of Cache Creek rocks, extends along the east side of the South Fork, crosses Bridge river opposite the mouth of the South Fork, and extends in a northerly direction beyond Gun lake. A smaller area of diorite outcrops above the wagon road near Fivemile creek. Its width and extent, however, could not be determined.

Granitic Rocks

The western border of the district examined touches the edge of the extremely irregular boundary of the Coast Range granitic batholith. The granitic rocks are prevailingly fresh and light coloured and vary in composition from granodiorite to diorite. They invade the Cache Creek series, but no portion of the main granitic mass was found in contact with the Cretaceous rocks. Large sills 1,000 feet or more in width of granodiorite porphyry, which are considered to be apophyses of the batholith, do cut the Lower Cretaceous rocks, so that in this district, at least, the granitic batholith must be considered as of post-Lower Cretaceous age.

Economic Geology.

The mineral resources of the Bridge River district may be described under:—

(a) Gold deposits.
(b) Silver-copper deposits.
(c) Antimony deposits.
(d) Placer gold deposits.
(e) Coal.

Of these the gold deposits are as yet the only commercially important deposits of the district.

Canada
Department of Mines
HON. L. CODERRE, MINISTER, A P LOW DEPUTY MINISTER

GEOLOGICAL SURVEY
R W BROCK, DIRECTOR

GEOLOGY | OUTLINE MAP

C.O.Senécal, Geographer and Chief Draughtsman

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MAP 105A
(Issued 1913)

CADWALLADER CREEK MINING AREA, LILLOOET MINING DIVISION, B.C.

To accompany Summary Report by A.M.Bateman, 1912

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GOLD DEPOSITS

Under this class are included free milling gold ores and refractory gold ores. The former are the more important and are to be found in the Cadwallader and McGillivray Creek sections. The refractory ores occur in the vicinity of Eldorado creek, Holbrook gulch, and a few other scattered localities.

Cadwallader Creek Section[1]

The Cadwallader Creek section is the most important part of the Lillooet Mining division and includes the only mines at present being worked, namely the Coronation, Lorne, and Pioneer. It is in the vicinity of Cadwallader creek and lies about 70 miles west of the town of Lillooet with which it is connected by a wagon road. The area within which the mines are located is about 3½ miles long and about 3,000 feet wide.

Unfortunately the greater part of the mining area is heavily forested and covered by a deep mantle of drift which renders prospecting very difficult.

It is claimed that the two largest mines have together produced $255,000, the larger part of which was obtained by crude treatment in arrastras, entailing considerable loss.

Geological Formations.—The formations underlying this section consist of the Cache Creek series and intrusive bodies of augite diorite. The Cache Creek series is here composed of cherty quartzites, argillites, volcanic tuffs, agglomerates and serpentine and associated with them are some conglomerates, slates, and sandstones with a few thin beds of limestones. The rocks are highly altered and have undergone such extreme folding, crumpling, and mashing that they are now almost unrecognizable. They are intruded by two elongated stock-like masses of diorite, one of which extends from east of the Pioneer to west of the Lorne and appears on the north side of Bridge river near the Wayside mine. This belt includes the Pioneer, Coronation, Lorne, and Wayside mines and many prospects. The other belt extends along the South Fork and includes the Forty Thieves group. The composition and structure of the diorite has already been described.

Ore Deposits.—The ore deposits are found in the diorite and in this region no instance is known in which valuable deposits occur outside the diorite area, nor is it probable that the veins within the diorite can be traced across the contact into the adjoining Cache Creek rocks as these rocks do not lend themselves readily to fracturing. It may be expected then that veins located in the diorite near the contacts will pinch out or shatter at no great distance beyond the contract. This has been shown in the case of the Little Joe vein. Thus, it is within the diorite belt that other veins may be looked for.

The ore deposits consist of banded fissure veins with well-marked crustification. They occupy a N. 80° W. system of fissuring. These intersect a minor mineralized system of fissuring in an east-west direction and both have been slightly faulted by still later fractures.

Subsequent to the filling of the fissures by vein material, compressive force was exerted upon them which resulted in an intense shearing of the diorite adjoining the veins and in a minute, parallel, step-faulting or slickensiding of the vein fillings, in an up and down direction along the lines of previous banding, and produced the characteristic ribbon structure. The veins are further characterized by numerous pinches and swells along their strike. These have been produced by one side of a warped fissure moving past the other so that divergent

[1] See map—Cadwallader Creek Mining Area.

warps became superimposed, giving rise to a swell, and convergent warps giving rise to a pinch. This has given the veins a certain irregularity in width. The pinches are in places too narrow to be profitably worked, but where they show a decided crustification or banding it is a rather general rule that the ore will continue beyond the pinch and open up into another swell of workable size. The walls are usually clean and sharply marked off from the vein material. Excepting for the pinches and swells the veins show a remarkable persistency of width and length, some of them having been exposed for over 900 feet. They vary in width from 6 inches to 7 feet. With a few exceptions, the veins at the easterly end of the diorite belt are small and those at the western end are larger. The greatest proven depth of the veins is about 250 feet, but as the fissures are persistent and enclosed in a homogeneous plutonic rock there is no reason why they may not extend to a considerably greater depth.

The ore itself consists of a gangue of white 'ribbons' of quartz separated by thin bands of slickensided darker material which is probably made up of finely crushed arsenopyrite, pyrite, and chlorite. Small drawn-out particles of polished gold may also be seen along these dark slickensides. The quartz, except where stained by iron oxides, is a hard, massive variety and is free from vugs and cavities. Pyrite, arsenopyrite, tetrahedrite, and free gold are sparingly disseminated throughout the quartz.

The gold occurs as native gold and small particles of it may be seen scattered throughout the quartz. In a few veins it forms bonanzas. Gold may be obtained by panning the quartz from almost any of the outcrops. The ore is not wholly free milling as a minor percentage is contained in the sulphides.

The diorite wall rock of the veins has been leached and altered by the mineralizing solutions, by means of which the dark minerals have been replaced by quartz, calcite, arsenopyrite, and pyrite and it is now a dense white, hard rock which in some places contains up to 0·4 ounce gold per ton. The amount of alteration decreases outward from the veins for a distance of 6 to 10 feet where the diorite is normal in character. The gold content of the veins varies in different parts of the area and in individual veins, and because of this it is difficult to give an estimate of the average value of the ore. Some of the ore-shoots, it is claimed, have yielded $65 or more to the ton while no parts of any veins so far mined have proved to be absolutely barren.

The mining has been chiefly in the upper oxidized portion of the veins and it is to be expected that the oxidized portion will have a somewhat higher value than the unaltered ore below the zone of oxidation. The maximum depth of oxidation is about 150 feet. There is no evidence to show that any change of values either greater or less, may be expected with increased depth of mining below this level.

Coronation Mines Ltd.

General.—This company owns a group of claims on the north side of Cadwallader creek, about 10 miles east of Bridge river and at an elevation of about 3,800 feet above sea-level. The property was located in 1898 and was known as the Ben d'Or mine until 1911 when it was taken over by the present company. Under the direction of Mr. Charles Copp, systematic development work is being carried on until more machinery is installed to efficiently treat the ore.

Development.—Four veins have been developed on the property. One of them known as the Little Joe vein has been intermittently mined since the time it was discovered and the others are just being opened up. The Little Joe vein outcrops on a steep hillside and dips about 60° to 70° into the hill. It has been opened up by four tunnels. The upper or No. 1 tunnel has been driven on the

strike of the vein for a distance of 250 feet and has attained a depth of 30 feet at the face. The ore above this has all been stoped. No. 2 tunnel has a total length of 750 feet. In No. 3 tunnel a cross-cut driven through solid diorite has intercepted the vein at a distance of 230 feet. From this point the vein has been followed 370 feet to the east. The work was discontinued because of a pinch in the vein. To the west it has been followed until the tunnel penetrated the surface wash, a distance of 240 feet. At a point about 140 feet back from the western face the vein was found to split and was followed to the southwest for a distance of 135 feet where the surface wash was again encountered. Tunnel No. 4 is a cross-cut tunnel penetrating the hill in a northerly direction for 540 feet. This was intended to be used as a main working tunnel, but unfortunately was driven without regard to the geological formations and passed through the Cache Creek rocks west of the point where the vein disappeared at the contact between them and the diorite. Later, at a point 350 feet from the portal, a cross-cut was run to the east, in the diorite, and cut the vein at a distance of 300 feet. At this point the vein is being developed by east and west drifts and by a raise up to No. 3 drift.

Geology.—The group of claims is located about a mile from the eastern end of the diorite area, and along the southern contact between it and the Cache Creek rocks. The contact crosses the lowest tunnel near the portal but the veins and workings are located entirely within the diorite. The diorite at this point intrudes serpentine and, where shown in the lower tunnel, forms a contact zone about 100 feet wide, grading from pure serpentine at the portal through a zone of diorite with included and partially assimilated fragments of serpentine, into pure diorite. The serpentine does not lend itself readily to fissuring and because of this the vein shatters and disappears within a short distance from the contact.

Veins.—The Little Joe vein has been exposed by underground workings for a distance of 850 feet and has been proved to a depth of 250 feet. It has a strike of N. 80° W. and dips northeast into the hillside. The walls are clearly and sharply defined and the vein is very persistent.

In No. 1 tunnel the vein is exposed for 250 feet and the width, which is here of the widest portion of the vein, varies from 1½ to 5 feet. In the face the width is 18 inches but 15 feet above it pinches to 5 inches and at the surface is 5 feet. The quartz is more massive than in other parts of the vein and exhibits less ribbon structure. The workable ore is confined to a shoot 18 inches wide and the remainder of the quartz is of low grade. The ore has been stoped from this level to the surface. In No. 2 tunnel the vein was followed for 710 feet. Many pinches and swells occur and the width varies from 4 to 30 inches. At a point about 450 feet from the portal the vein pinches to 3 inches, but 130 feet beyond again widens to another workable ore-shoot containing a high gold content. The ore has been removed from above this tunnel for a distance of 400 feet, but 300 feet yet remains, and 150 feet of this is good ore. In No. 3 tunnel the vein is followed for 615 feet. Throughout this distance it varies considerably in width and only a part of it is of sufficient size to be worked. At the eastern end of the vein is an ore-shoot about 20 inches wide which has yielded the spectacular specimens of the Coronation mine. It is stated by the previous owners that the ore from this shoot, with all the rich specimens removed, yielded $60 per ton on the plates. Part of this ore has been stoped up to No. 2. Another ore-shoot has been traced for a distance of 280 feet. This varies from 12 to 28 inches in width and a 20-ton lot is said to have yielded $65 to the ton on the plates. From the end of this ore-shoot to the face of the tunnel, about 200 feet, the vein is pinched, but as the crustification of the vein is continuous and well marked it is probable that it will continue beyond the squeeze and again open into another swell of workable size, as is the case in No. 2 tunnel. Part of the ore has been removed above this tunnel but it is all solid ground below it. In tunnel No. 4 the vein has been cut,

lately, at a point 76 feet below the long ore-shoot exposed in No. 3 tunnel and has a width of 7 to 17 inches. This point is 220 feet below the face in No. 1 tunnel and is the deepest point yet reached on the vein. It is probable that further drifting to the east along this level will result in finding other pinches and workable swells similar to those in the upper levels. The vein in No. 2 tunnel has been followed for 750 feet east of this point and it is likely that the vein on this level will continue for at least the same distance. To the west, however, the vein is not likely to extend more than about 200 feet, and perhaps less, beyond the point where it is cut in No. 4 tunnel, because beyond this is the serpentine of the Cache Creek series into which the veins have not been found to extend. The vein on this level is strong and well defined and there is no reason to suppose that it should not extend to greater depth.

The Countless vein is exposed on the claim adjacent to and west of the Little Joe claim. It has the same strike as the Little Joe vein and is almost directly in line with it. As only 265 feet lie between the exposed ends of the two veins they may possibly be the same one, but this is difficult to determine by surface work on account of the heavy mantle of drift. The vein is exposed for a distance of 737 feet along the surface by a series of 12 open-cuts. The width varies from 5 to 60 inches and averages about 22 inches. The general character of the vein is similar to that of the Little Joe vein. It is stated that the average of all the samples taken from all of the surface cuts gave a value of $20 to the ton in gold. A cross-cut tunnel is at present being driven to intercept the vein at a distance of 520 feet and at a vertical depth of 200 feet below the outcrop. At the time of examination the tunnel had already been driven 324 feet.

Two other small veins have recently been uncovered on the Countless claim, one 6 and the other 13 inches wide. Both of these are quartz veins highly oxidized at the surface and yield a good prospect of gold upon panning.

Values.—The gold content of the ore varies considerably in different parts of the veins. The previous owners state that 8,000 tons have been milled and yielded $196,000 or an average of $24 to the ton. A 20-ton lot from the rich ore-shoot in No. 3 is stated to have yielded $65 to the ton on the plates. The tailings are said to average $11.60 in gold to the ton.

Equipment.—The equipment consists of a mill and a 350-foot tramway leading from the mill to No. 3 tunnel. The mill contains a receiving ore bin of 75 tons capacity, a 10×12-inch jaw crusher, automatic feeders, and two 5-stamp batteries with amalgamating plates. No machinery has yet been installed for the saving of concentrates, but it is the intention of the present company to equip the mill with suitable concentrating machinery. Sufficient water power to operate the mill is obtained from Cadwallader creek.

Lorne Group.—The Lorne Amalgamated Mining Company controls the Lorne, Golden King, Woodchuck, and three other mineral claims, situated about 1½ miles west of the Coronation mine. This company is a close stock company with a capitalization of $100,000. Mr. William Sloan, of Nanaimo, is president. These claims were staked in 1897 and have been worked since that time in a desultory manner by local owners who treated the ores in home-made arrastras.

Development.—The most important veins on the property that have been opened up by underground workings are the King vein, the Wedge vein, and the Woodchuck veins. They all outcrop on a steep hillside and have been developed by tunnels. The King vein has been opened up by 4 tunnels, of which No. 1 is the highest. It is now caved in but is said to have a length of about 250 feet. All the ore from this tunnel has been stoped through to the surface. Tunnel No. 2 is 50 feet lower than No. 1 and has a total length of 315 feet. The greater part of the vein exposed by this tunnel has been stoped up to No. 1. Tunnel No. 3 is 54 feet lower than No. 2 and has a length of 266 feet. Tunnel No. 4 is

90 feet below No. 3 and penetrates the hill in a northerly direction for 240 feet. This was planned to be used as the main working tunnel for the King vein, but unfortunately no attention was paid to the dip of the vein and the tunnel did not intercept it.

The Wedge vein has been opened up by two tunnels. The upper or No. 1 tunnel is now caved in. The lower tunnel is at the same elevation as the King No. 2 and follows the vein into the hill for a distance of 206 feet.

The Woodchuck veins are opened by two tunnels. No. 1 tunnel cuts a vein at a distance of 53 feet which is then followed to the east for 88 feet. No. 2 cross-cut tunnel is 160 feet long, at the end of which a drift has been run for a distance of 80 feet. On another vein a shaft has been sunk to a depth of 70 feet.

Geology.—All of the Lorne workings lie within the diorite area. The Cache Creek rocks cut across the southern corner of the Woodchuck claim and across the northern end of the Lorne and Golden King claims but do not affect the veins so far as is known,

Veins.—Eight veins and a few small stringers have been exposed on the Lorne group. Of these the King, Wedge, Shaft, and Woodchuck veins are the most important. Mining operations have as yet been limited to the King and Wedge veins.

The King vein strikes N. 40° E. and dips 65° northwest. The total length exposed is about 400 feet and the maximum depth attained is about 240 feet. In King No. 1 tunnel the vein has been exposed for about 250 feet, all of which has been stoped to the surface. Nearly all of these workings are now caved in but it is stated that the width of the vein varied from 4 to 6 feet, and that the ore extracted was very rich.

In King No. 2 tunnel the vein is strongly defined and continuous. The average width is between 3 and 4 feet but in one place the fissure is 8·2 feet wide, 6 feet of which is solid quartz. The quartz is strongly ribboned and sparingly mineralized with arsenopyrite, pyrite, chalcopyrite, and tetrahedrite. The country rock adjoining the vein is altered, silicified, and mineralized with pyrite and arsenopyrite. Most of the ore between this tunnel and No. 1 has been removed. A body of ore about 30 feet long by 30 feet deep has been removed in an underhand stope at a point where the vein is 6 feet wide.

In King No. 3 tunnel the vein is a little wider than in No. 2 and less oxidized. No ore has been stoped from this tunnel. The King vein has not been cut in No. 4 tunnel but another small quartz vein has been cut near the face. This vein dips vertically, has an easterly strike, and is about 12 inches wide. It yields a good prospect of gold by panning.

The Wedge vein has been traced underground for a distance of 125 feet. The width varies from 5 to 27 inches and averages about 22 inches. The strike of the vein is N. 5° E. and dip 50° W. It is well defined between distinct gouge walls and exhibits the typical ribbon structure. Tetrahedrite, arsenopyrite, and pyrite are sparingly disseminated in the quartz. Small amounts of azurite and malachite occur in the upper oxidized portions of the vein.

The wall rock adjoining the vein has been leached of its dark constituents, and silicified and mineralized with small amounts of sulphide. No native gold can be seen in the altered rock, but a sample taken at intervals along the tunnel, at distances of 1 to 2 feet from the vein, yielded 0·03 ounce gold per ton.

In the Woodchuck tunnels, 4 veins have been exposed. The vein in the upper or Woodchuck No. 1 tunnel has been followed for 88 feet. It has a strike of S. 70° E. mag. and dips to the northeast. The width varies from $\frac{1}{2}$ to $5\frac{1}{2}$ feet and pinches and swells are numerous along both the strike and dip. Small amounts of arsenopyrite and pyrite are disseminated through a gangue of quartz. The lower Woodchuck tunnel cuts three small veins all of which dip to the northwest

and strike N. 75° E. mag. The first vein has a width of 12 inches and the second vein has a width of 22 inches. The third vein is 10 inches wide and shows decided ribbon structure. None of these veins are a continuation of the vein in the upper tunnel.

The Shaft vein has been opened by a vertical shaft which has a depth of 70 feet and is now filled with water. The vein is said to have maintained a width of about 3 feet for a depth of 60 feet, at which point it was found to be cut off by a fault. Specimens of ore on the dump show that the quartz is ribboned and contains pyrite, chalcopyrite, arsenopyrite, and tetrahedrite. It was necessary to roast the ore to obtain the gold by amalgamation. Near the shaft another vein, with a width of 2 feet, has been exposed by a small surface cut and the lower Wedge tunnel is being pushed ahead to intercept this vein at a depth of 30 feet.

Farther up the hillside on the Lorne claim large masses of quartz float are found which contain gold visible to the eye, but the vein which supplied the float has not yet been located.

Values.—It is not possible to obtain an average value of this character of ore by ordinary hand sampling unless by extensive methods and this was not deemed advisable. The statements of values here were supplied by the owners and were based upon mill runs. It is stated that the total production from the Lorne and King veins is about $55,000 and that the average extraction, by amalgamation, of the ore from the King vein was $17 per ton. In one summer $13,000 was extracted by treating the ore from King No. 3 tunnel in two arrastra beds, with an average yield of $80 per ton. This ore, however, was all from the richer oxidized portion of the vein. The average value of the ore in Wedge tunnel No. 2 is estimated to be $10 per ton, while the richer oxidized ore from the upper Wedge tunnel yielded $80 per ton from a 4½ ton lot. Some concentrates saved from the arrastra beds gave assays from $90 to $380 per ton and the tailings from the arrastra and mill assayed from $3 to $6 per ton. A representative sample of the altered wall rock in King No. 2 tunnel was assayed at the laboratory of the Department of Mines, Ottawa, and yielded 0·04 ounces gold per ton. A similar sample taken from Wedge No. 2 tunnel yielded 0·03 ounces gold per ton.

Equipment.—Previous to the installation of the mill all the ore was treated by means of home-made arrastras constructed of wood, of which there were three on this property. The lower arrastra was run by an overshot water wheel, 24 feet in diameter. On either side of the wheel is a driving pulley which is connected to the vertical shafts of two arrastras arranged on each side of the wheel. The beds are 12 feet in diameter and are paved with smooth blocks of hard diorite set in clay. The sides of the beds are stayed and rendered watertight. The vertical shafts carry arms to which are attached heavy blocks of diorite and these are dragged over the bed and crush the ore to a fine powder. Water and quicksilver are added and by continual stirring the gold is amalgamated. The sludge is intermittently drawn off from a spout at the top of the bed. Every two weeks a clean up is made and new drags and beds are put in. The two arrastra beds have a capacity of 2 to 3 tons per 24 hours. A remarkably clean extraction is made by this crude process. Later a gravity tramway and a 5 stamp mill were installed. The mill is equipped with ore bins, crusher, stamp battery, and amalgamating plates. No device has yet been installed to make concentrates. The mill is operated by a 48-inch Pelton wheel driven under a 270-foot head of water.

Pioneer Mine.—The Pioneer mine is situated about three-fourths mile east of the Coronation mine and at the extreme eastern end of the diorite belt. The mine was opened up by one man, who for eleven summers, single handed, mined and treated all his ore in a small arrastra and made a comfortable living by it. The property is now controlled by Mr. S. Ferguson and his brother.

Development.—Two veins have been discovered on the hillside above Cad-

wallader creek and have been developed by three tunnels. In the upper or No. 1 tunnel the vein was cut at a distance of 40 feet and followed for a distance of 42 feet. In No. 2 tunnel the vein was cut at a distance of 29 feet and followed to the east for 15 feet and to the west for 40 feet. In the lower or No. 3 tunnel a vein was cut at a distance of 78 feet and followed for 60 feet, and 18 feet beyond this a second vein was struck and followed for 103 feet. This vein has been partly stoped and an upraise has been put through to No. 2 tunnel. At a point 750 feet west of No. 3 tunnel a cross-cut tunnel is being run to intercept the vein and to be used as a working tunnel. At the time of examination it had been driven a distance of 270 feet.

Veins.—Besides the two veins opened up in the main No. 3 tunnel, one stringer and an irregular quartz vein have been exposed in cross trenches. These, however, are unimportant. The first vein exposed in No. 3 tunnel is characterized by pinches and swells along its exposed length of 60 feet. The average width is about 20 inches. The vein has a well pronounced ribbon structure and contains small amounts of arsenopyrite and pyrite in a gangue of quartz. No stoping has been done on this vein. The second vein is about 20 feet beyond the first and has a strike that would intersect the first vein at a distance of 105 feet to the west. Some ore has been stoped from the west drift and in the east drift the ore has been removed up to No. 2 tunnel. At a point 15 feet above the drift the vein has been faulted a distance of 10 feet to the hanging wall side. The width of the vein varies from 1 to 4 feet and has an average of about 2 feet. The gangue is ribboned quartz and contains a little arsenopyrite and pyrite, and has been partially oxidized. In No. 2 tunnel, 47 feet above, this vein is exposed by a drift 55 feet in length. It is still strongly defined but narrower and more oxidized. In No. 1 tunnel the same vein is followed for a distance of 40 feet and the width is about 16 inches. A fault has cut across the vein and moved it uphill so that there is a possibility of finding the upper portion of the vein outcropping on the hillside above the tunnel.

A cross-cut tunnel, located 750 feet west of No. 3, is being run to intercept the main veins. These veins, however, were not encountered at the calculated distance, nor is it likely that they will be cut in this tunnel because the diorite in which the veins occur does not extend as far west as the cross-cut tunnel.

Values.—The previous owner claimed to have been able to treat 600 to 700 pounds of ore per day in the arrastra and make an average wage of $10 per day. This equals an extraction of about $30 in gold per ton. It is stated that some of the ore yielded $60 per ton by treatment in the arrastra. An assay of the arrastra tailings yielded $22.80 per ton.

Equipment.—The only equipment to the property is a small arrastra with one 8-foot bed, capable of treating 600 to 700 pounds of ore per day. Power is supplied by a water-wheel situated on the bank of the creek.

Blackbird Claim.—The Blackbird claim is located within the diorite belt, about one mile east of the Lorne. The diorite here is similar to that of the Lorne group.

A tunnel has been driven in on the vein for a distance of 75 feet. At the portal the vein is 3 feet wide but, within 15 feet, narrows down to 6 inches, and 50 feet farther pinches out altogether. The quartz is a white, massive variety and lacks the typical ribbon structure. The gold content is said to be low.

Another vein, locally called the 'potato sack ledge' because of its extreme irregularity, outcrops near the eastern boundary of the claim and has been traced across the line on to the Ida May claim where it has been opened up by a tunnel. The width varies greatly. In one cut it is 4 feet wide, in another 13 feet, and in another a few inches. The quartz is a white, massive, hungry looking variety and is devoid of sulphides and ribbon structure.

Ida May Claim.—The Ida May claim adjoins the Blackbird to the east and is likewise within the diorite area.

There are two veins on the property both of which have been opened up by tunnels. The upper tunnel is now caved in and the vein could not be seen. In the lower tunnel the vein has been cut at a distance of 100 feet and a drift has been run to the east for 125 feet and to the west for 30 feet. It has a vertical dip and a strike of N. 20° W. mag. The width varies from 4 to 20 inches. The quartz is slightly ribboned and contains small amounts of pyrite and much iron oxide.

Alhambra Claim.—The Alhambra claim adjoins the Lorne on the east and is within the diorite area. Two veins have been opened up on the property, one by a shaft and the other by a tunnel. The shaft is now inaccessible and the vein could not be seen. The tunnel has been driven for 275 feet along a vein with a strike of N. 35° E. The vein has numerous pinches and swells so that the width varies from 6 to 36 inches but maintains an average of about 22 inches. The quartz is very finely ribboned and splits readily along the slickensided surfaces. Arsenopyrite and pyrite are sparingly disseminated in the quartz. The value of the ore is not known, but gold may be obtained by panning the crushed quartz.

Cosmopolitan Claim.—The Cosmopolitan claim lies on the north side of the Lorne group and is just within the diorite area. The contact with the Cache Creek rocks passes a short distance beyond the northern line of the claim. A shaft has been sunk to a depth of 25 feet on a vein with a vertical dip and a strike of N. 45° W. It has a width of 26 inches and is bounded by sharply defined walls of slightly altered diorite. The quartz is partially oxidized and contains small amounts of pyrite and chalcopyrite. In a tunnel 250 feet west of the shaft is a vein which is in line with the shaft vein and may possibly be the same one. It is more oxidized and mineralized and exhibits more ribbon structure than the other.

Wayside Mine.

The workings of the Wayside mine are on the Wayside mineral claim, one of a group of 6 claims owned by the Bridge River Gold Mining Company, of Cincinnati, Ohio. The claims are located on the north side of Bridge river about 2 miles above Gun creek and 52 miles from Lillooet. Connexion with Lillooet is made by means of the Bridge River wagon road. The Wayside claim was staked in 1900, development work started in 1907, and in 1910 the claim was sold to the present owners who then acquired the adjoining claims. It is the intention of the present company after doing more preliminary development to install a mill and commence mining operations.

Development.—The property has been developed by means of 4 tunnels and a number of open-cuts. The upper or No. 1 tunnel has a length of 25 feet. No. 2 tunnel is 235 feet lower than No. 1 and has a length of 125 feet. No. 3 tunnel is 90 feet lower than No. 2 and has a length of 135 feet. No. 4 tunnel lies 128 feet east of No. 3 and 70 feet lower and has a length of 109 feet. No development other than tunneling along the veins has yet been done.

Geology.—This property lies in what is probably a part of the same diorite belt as that in which the Lorne and other properties are located. The diorite could not be traced between the two places on account of the heavy mantle of drift. The conditions, however, are the same and the diorite resembles that of the Cadwallader Creek diorite except that it is more fractured. It breaks across the strike of a series of quartzites, argillites, slates, conglomerates, sandstone, and limestone, all of which are included in the Cache Creek series. Its eastern contact follows the draw above the Wayside cabin.

Veins.—Two, perhaps three, parallel veins have been developed on the property. They cut into the hill nearly at right angles and outcrop down the face of the steeply sloping hillside. The occurrence of these veins is similar to those of the Lorne and Coronation mines.

In No. 1 tunnel a vein, with a strike of N. 30° W. and a dip of 45° N.E., has been exposed for a length of 25 feet. It is 20 inches wide and is composed of solid, massive, white quartz without ribbon structure. The structure and position of the vein suggest that it is a different one from that in No. 2 tunnel which has been opened up 235 feet lower down the hill. The vein in No. 2 has a strike of N. 30° W. and dip 45° N.E. and has been exposed for 115 feet. It has an average width of about 12 inches but swells to 20 inches and pinches to 2 inches. The vein occurs in a brecciated fault zone of altered diorite which is sparingly mineralized and contains small quartz veinlets parallel to the main vein. The quartz is strongly ribboned and contains small amounts of arsenopyrite, pyrite, chalcopyrite, and free gold. At the mouth of the tunnel there is an ore dump containing 12 to 15 tons of ore and numerous specimens containing visible gold are scattered through it. In No. 3 tunnel, what is supposed to be the same vein is exposed for 135 feet. It has a strike of N. 25° W. and dips to the northeast at an angle of 50°. The dip and position of this vein show that it is not a continuation of the vein in No. 2 tunnel but a parallel one which passes to the west of it. The vein is contained in walls of brecciated diorite and is composed of quartz and brecciated rock and does not show any prominent ribbon structure. It is not as strongly defined as those in the upper tunnels and in places almost pinches out. The maximum width of the quartz is 10 inches. No. 4 tunnel has been driven in along a brecciated shear zone of diorite for 109 feet. Small amounts of quartz, calcite, and pyrite are scattered through the gouge material but there is no regular vein.

Values.—A 1000 pound mill sample of ore taken by the owners from No. 2 tunnel, crushed to 100 mesh, yielded $38 per ton in gold, and 82 per cent of the gold content was found to be free milling. The brecciated material from No. 4 tunnel was sampled and found to contain a trace of gold per ton.

Forty Thieves Group.

This group is located along the South Fork of Cadwallader creek about 5 miles below the Lorne and at an elevation of 3,000 feet above sea-level. The claims have been staked for some time but little work has been done to develop the property.

Geology.—Another belt of diorite separated from the Lorne diorite by a narrow band of Cache Creek rocks, follows the north side of the South Fork, and it is in this diorite that the Forty Thieves vein occurs. The diorite belt is a narrow body elongated in a northwesterly direction and has been found to extend across Bridge river and beyond Gun lake. It is minutely traversed by small quartz veinlets which in many places contain sulphides and indicate that this diorite has been subjected to the action of mineralizing solutions. Such being the case, detailed prospecting may reveal other veins.

Vein.—The vein has been exposed for a distance of 200 feet along the top of a 200-foot vertical cliff above Cadwallader creek. It has a strike of N. 40° W. and dips 40° N.E. The average width is about 3 feet. The gangue is massive quartz and contains very small amounts of pyrite, chalcopyrite, azurite, and malachite. The vein differs from the Lorne vein in that it does not exhibit the ribbon structure typical of the high grade ores.

Some rich specimens are reported to have been taken out of this vein but the quartz as a whole is barren looking and the specimens probably came from pockets.

McGillivray Creek Section.

The McGillivray Creek section embraces a small area in the vicinity of McGillivray creek. This creek heads on the divide opposite the headwaters of Cadwallader creek and flows in a southeasterly direction into Anderson lake. The mouth of McGillivray creek is about 37 miles from Lillooet and is connected with it by trail and also by a line of power boats on Seton and Anderson lakes.

This section has been prospected a number of years and many mineral claims have been staked, but mining work has been done on only one property, that of the Anderson Lake Mining Company.

Geology.—The geology of this section differs from that of the Cadwallader Creek section in that there are no intrusive bodies of diorite with which the ore is associated. The Cache Creek series is represented here, and underlies the greater part of the area. It is made up of slates, argillites, quartzites, serpentine, and greenish coloured volcanic rocks, all extremely altered, mashed, foliated, and contorted. The slates and argillites have been crumpled and altered to mica shists. The quartzites have been minutely folded and sheared and the volcanic rocks have undergone extreme alteration. The more pronounced metamorphism here is due to the presence of outliers of the Coast Range granitic batholith which have intruded the Cache Creek series in the form of sills, dykes, and stock-like masses.

The granitic rocks range in composition from normal light coloured biotite-hornblende granites to granodiorites and diorites. The dyke rocks are granite-porphyries containing large phenocrysts of feldspar embedded in a groundmass of quartz and feldspar.

Veins.—The ore deposits of this section occur altogether in the Cache Creek rocks. They consist of quartz veins, extremely irregular in width, length, and dip. The walls are poorly defined and very irregular. The quartz is usually white and massive and contains small amounts of pyrite, and chalcopyrite. The values are in gold and appear to be irregularly distributed in shoots in the quartz.

The veins appear to be connected with the granitic sills and dykes.

Anderson Lake Mining Co.

This company owns a group of claims on the north side of McGillivray creek about 5 miles from Anderson lake and at an elevation of 3,725 feet above sea-level. A wagon road runs from the mine to Anderson lake and connexion is made from there to Lillooet by means of power boats on Anderson and Seton lakes. The property has changed hands a number of times and has been worked intermittently. The last work was done under lease in 1910.

Development.—The veins outcrop down the slope of a steep hillside and have been developed by three tunnels and a number of open-cuts. The upper or No. 1 tunnel is now caved in but is said to have a length of 450 feet. No. 2 tunnel is 670 feet long and contains one stope 450 feet long, 45 feet high, and 7 to 30 feet wide. The lowest or No. 3 tunnel is 150 feet below No. 2 and is 175 feet long.

Veins.—One vein with a north and south strike (mag.) and dip 40° E. has been developed in Nos. 1 and 2 tunnels. It has been traced by underground and surface workings for a distance of 600 feet or more and has been stoped for 45 feet above the tunnel. In the back of the stope the vein is strongly defined with well marked gouge walls and has a width of 14 feet. At the bottom of the stope the vein is 20 feet wide, of which 17 feet is quartz and the remainder is composed of included fragments of country rock. The quartz is a hard white massive variety and contains only a small amount of pyrite.

The walls are in many places irregular, poorly defined, and intersected by branching veinlets of quartz joining the main vein. One such minor stringer has

apparently been followed in the last 135 feet of the tunnel, and in the face is only a few inches wide. In the stope above, however, the main vein has been followed along its proper course and has a width of 6 to 14 feet.

What is apparently a separate vein, because lower and west of this easterly dipping vein, has been developed in No. 3 tunnel. It has the same strike and dip but its width is only 3 to 4 feet. It has been followed for 175 feet and stoped to a height of about 40 feet and exhibits the same irregularities as the upper vein.

Values.—The values apparently do not occur in regular ore-shoots in the vein but in irregularly scattered pockets. Many rich specimens have been taken from such pockets in the oxidized portions of the veins.

It is stated that $35,000 has been extracted from the oxidized portion of the vein with an average yield of $25 per ton on the plates. The value of the ore at present exposed in the stopes is admitted to be less than $2 per ton.

Equipment.—The mine is equipped with a 10-stamp mill and a 750-foot gravity tramway leading from No. 2 tunnel. The mill contains a grizzly, a jaw crusher and two 5-stamp batteries fitted with automatic feeders, amalgamating plates and mercury traps. Power is provided by a 48-inch Pelton wheel driven under a 300-foot head of water.

Ruby Claim.—The Ruby claim is located a short distance south of the Anderson Lake mine. One vein with a strike of N. 35° W. has been opened up by a surface trench and a tunnel 40 feet in length. The country rock is slate and the vein follows the strike of the slates. The walls are well defined but the vein is very irregular and varies in width from 2 to 22 inches. The quartz is white and massive and contains a small amount of pyrite. The vein was sampled and was found to contain a trace of gold per ton.

Moose Group.—The Moose group consists of three claims located on the divide between McGillivray and Roaring creeks at an elevation of 3,175 feet above sea-level. The country rock consists of sheared argillites, quartz schists, and a few thin beds of limestone. The ore body is a series of irregular segregations of quartz, from 2 to 18 feet wide, following a definite line of fracturing which has been traced for about 800 feet. The quartz is a white glassy variety containing many fragments of country rock but devoid of sulphides. The value does not exceed 50 cents per ton.

A number of prospects were examined in this section but they are all somewhat similar to those already described.

Eldorado Creek Section.

The Eldorado Creek section is located around the head-waters of Eldorado and Taylor creeks, and lies about 9 miles north of the mouth of Gun creek.

During the autumn of 1911 and the spring of 1912 prospecting in this section resulted in the discovery of a few gold-bearing deposits. Little development work has yet been done and the properties are still in the prospecting stage.

Geology.—The rocks in which the ore deposits have been found are of Lower Cretaceous age. They consist of conglomerates, sandstones, slates, and black compact quartzites. Interbedded with these are volcanic rocks and a few thin beds of limestone. The series is intruded by sills of granite porphyry, some of them 1,000 feet wide.

Ore Deposits.—The ore deposits so far located consist chiefly of small veins of arsenopyrite and pyrite containing gold. Masses of float composed of arsenopyrite and pyrite, which must come from large deposits, have been found on many of the hillsides but the source of the material has not been located.

The veins are associated with granodiorite porphyry dykes which intrude the Lower Cretaceous series, and in some places the dykes themselves are heavily

mineralized. Only the oxidized portions of the deposits have so far been exposed and these yield rich gold values by panning. It is to be expected, however, that below the zone of oxidation the greater part of the gold will not be free but contained in the arsenopyrite, and the gold value per ton will be less, because, in ore of this class, it has undergone a certain amount of concentration during the process of oxidation.

White and Bell Group.—This group, owned by Messrs. White and Bell, is located at the head-waters of Eldorado creek at an elevation of 6,410 feet above sea-level.

A tunnel has been driven in on the strike for a distance of 40 feet. The rock is altered and oxidized to a disintegrated mass. With the present amount of development it is difficult to determine the exact nature of the deposit, but it appears to be a series of small parallel veins with the intervening country rock heavily mineralized. This mineralized country rock and vein material yields a good prospect of gold by panning. The veins are filled with solid arsenopyrite, pyrite, and chalcopyrite, and the country rock is disseminated with the same minerals. Another small tunnel, 300 feet to the west, has been driven in on similar stringers.

Wide West Group.—This group is owned by Messrs. Taylor and Shuster. It is located along Taylor creek about one mile from the divide between Taylor and Eldorado creek.

The rock formations here strike N. 40° W. and consist of highly inclined beds of volcanic rocks, slates, and a bed of crystalline limestone. This bed of limestone has been partly replaced by pyrrhotite and a minor amount of chalcopyrite and quartz and is a replacement ore deposit. The limestone has been exposed for a width of 28 feet and all of this has been wholly or partly replaced. In some places the pyrrhotite occurs as solid masses, in other places constitutes 60 per cent of the rock. As the ore in this deposit is dependent upon the presence of the limestone bed, the extent of the deposit may be determined by following the limestone.

Victoria Claim.—The Victoria claim is located at the head of Taylor creek. It is underlain by quartzite and volcanic breccia and is intruded by an andesite porphyry dyke about 12 feet wide which has a strike of about N. 40° W. A vein varying in width from 10 to 36 inches has been traced along the hanging wall side of the dyke for a distance of 75 feet. Both vein and dyke have been cut off at the southeast end by a fault. The displaced end of the vein has not been found and the displacement of the fault is unknown. The gangue matter is quartz and is well mineralized with arsenopyrite, pyrite, chalcopyrite, pyrrhotite, zinc blende, and stibnite. In places the sulphides form solid masses of ore.

The ore was sampled and found to assay, 0·54 ounces gold, 2·24 ounces silver, 8·61 per cent zinc, and 9·94 per cent antimony per ton.

Bonanza Creek Claims.

A few claims have been located by Mr. Pearson in Bonanza Creek basin about one-half mile north of Eldorado creek. The ore deposit consists of a decomposed granite porphyry dyke in which are a number of small veins filled almost entirely with arsenopyrite and minor amounts of chalcopyrite, pyrrhotite, pyrite, and zinc blende. Some pieces of float composed of the same materials have been found, but no vein over 3 inches in width had been located at

the time of examination. A number of these small veins cut across the oxidized and decomposed dyke rock. A considerable amount of free gold may be obtained from this material by panning.

A few other arsenopyrite-gold veins occur in granite porphyry dykes, or near porphyry dykes, along the summits between Eldorado, Taylor, and Bonanza creeks.

Spokane Group.

This is a group of claims owned by Dr. Christie, of Lillooet. They are located in Holbrook gulch at the head-waters of Big creek, a tributary of the North Fork of Bridge river.

The rocks of this section consist of serpentine, quartzite, and argillites of the Cache Creek series, intruded by sills and dykes of granite porphyry. These granite sills and dykes are directly connected with larger granite masses which are exposed east and west of this point.

A vein directly associated with the granite porphyry intrusives, has been exposed by two tunnels and a series of surface trenches. Unfortunately most of the surface cuts were caved in at the time of examination. In one open-cut above the tunnel the vein has a width of 7 feet. In the upper tunnel where it was cut at a distance of 20 feet, the width is 4½ feet. The lower tunnel, at an elevation of 7,000 feet above sea-level, has been driven 165 feet but the vein has not been intercepted. The walls of the vein are poorly defined. Where the porphyry forms the wall rock it is altered and silicified due to the action of the mineralizing solutions. The gangue material consists of massive quartz mineralized with chalcopyrite, pyrite, and pyrrhotite. The value is in gold and copper.

Summit Group.

This is a group of three claims located at an elevation of 4,800 feet above Bridge river, on the summit between Alexander and Tyaughton creeks.

A basic dyke, 8 feet wide, strikes in a northerly direction across a series of quartzites, argillites, and chloritic volcanic rocks. Cutting across this dyke are a number of short parallel stringers of quartz containing arsenopyrite and pyrite. The gold content of these stringers is said to be $30 per ton, but they are small and their extent is limited to the width of the dyke which is only 8 feet. Sufficient stringers are not exposed to justify the working of the dyke as a whole.

Farther up the hill a tunnel was run to intercept an irregular quartz vein containing pyrite, arsenopyrite, galena, and zinc blende but did not cut it. The vein has been traced on the surface for some distance and was found to vary in width from 2 to 26 inches. In places there is 16 inches of solid sulphide. The deposit, however, is small and extremely irregular.

Rhodes Group.

This group is owned by J. Dunlop, of Lillooet, and is located on Mission mountain one mile east of Mission pass at an elevation of 2,000 feet above Seton lake. All of the workings and most of the outcrop are now caved in or covered up.

The deposit is an irregular body of ore, apparently of some size, outcropping on a steep hillside along the border of a large mass of granite, intrusive into Cache Creek rocks. The deposit appears to be associated with and dependent upon the granite and may be looked for along its contact. The ore consists of an intimate mixture of pyrite and pyrrhotite with small amounts of chalcopyrite. Many assays have been made by the owner and have been found to vary from 0·02 to 7·25 ounces gold and 0·4 to 1·4 ounces silver. An assay of a representative sample gave 0·34 ounce gold and 0·86 ounce silver.

SILVER-COPPER DEPOSITS.

Empire Group.

This is a group of three claims owned by the McGillivray Mountain Mines, Ltd., which is a stock company capitalized at $1,000,000, with Mr. S. A. Cauley, of Chilliwak, as president, and J. M. Williams as manager. The claims are located at the head of Roaring creek near upper McGillivray creek and the workings are in a steep basin above a small glacier at an elevation of 8,000 feet above sea-level, or about 1,500 feet above timber line.

These claims were staked some 12 years ago, but were subsequently dropped because of low gold values. Since then they have been intermittently held by a number of prospectors, none of whom ever completed the assessment work upon them. They were finally restaked in 1911 by the present owners who plan to do considerable development work.

Geology.—The rocks of these claims consist of sheared quartzites, altered argillites, mica schists, chloritic schists, serpentine, and a few thin beds of limestone. They are a part of the Cache Creek series but are extremely metamorphosed in this locality. They are intruded by sills and dykes of 'bird's-eye porphyry' or granodiorite porphyry which contains large phenocrysts of feldspar in a groundmass of quartz, feldspar, hornblende, and biotite.

Veins.—The ore deposit is a large quartz vein which cuts the Cache Creek rocks nearly parallel to their strike and is associated with one of the granodiorite porphyry dykes. The vein strikes S. 80° E. and dips 70° S. It has been traced by a series of open-cuts and one short tunnel for about 1,000 feet and in this distance varies in width from 3 to 14 feet. In the tunnel the walls are well defined and consist of an impure serpentine. In the lower cuts they are less clearly defined and consist of argillite.

The quartz is a hard, white, massive variety containing small amounts of pyrite, chalcopyrite, zinc blende, stibnite, azurite, malachite, and a little tetrahedrite. Silver telluride and silver bromide are reported to occur in the quartz, but no trace of any could be seen.

It is stated by the owners that assays of specimens have yielded from $76.40 to $149.60 in silver and copper, and that a 50 pound sample, concentrated 16-1, gave a value of $344.95 per ton of concentrates in silver and copper. A sample across the face of the tunnel yielded by assay at the Department of Mines, Ottawa; gold, trace; silver, 0·60 ounces; copper, trace. A sample from the upper cut yielded; gold, trace; silver, 5·40 ounces; copper, trace.

ANTIMONY DEPOSITS.

A small deposit containing antimony is located on the north side of Bridge river near Gun creek. It is associated with a granodiorite porphyry dyke which intrudes some quartzites, argillites, and agglomerates of the Cache Creek series. The deposit consists of a quartz vein containing galena, chalcopyrite, and stibnite (the sulphide of antimony). These minerals are disseminated through the quartz and also occur as lenses of solid sulphide. These lenses, however, are not continuous and do not exceed 4 inches in width. The gold and silver content of the veins is said to be low and the amount of stibnite exposed is not sufficient to be of commercial value as an ore of antimony.

PLACER GOLD DEPOSITS.

In the early days of the Bridge River district placer gold mining was the im-

portant industry. Much gold has been extracted from the gravels of lower Bridge river and the mouth of the South Fork, but at present placer gravels are being worked only along the South Fork below the mouth of Cadwallader creek.

The auriferous gravels of the South Fork occur as river and bench gravels on a serpentine bed-rock. They are clean but coarse, and many large boulders are encountered. In a few places the bottom gravels are cemented by calcium carbonate and coarse gold may be seen in the cemented material. Only the lower 7 feet of the gravels is auriferous and through it the gold is rather evenly distributed, although many rich streaks are found. Both coarse and fine gold occur and it is often ragged, showing that it has not travelled far. The value of the gravel per yard could not be learned, but it is stated that with rich ground a wage of $18 per day per man is obtained by sluicing.

The auriferous gravels do not extend up the South Fork farther than the mouth of Cadwallader creek and do not extend up Cadwallader creek beyond the mining section. It is probable then that the gold was obtained from the erosion of the upper portions of the gold quartz veins of the Cadwallader Creek section.

Walker Hydraulic Mine.

This property is owned by a Cincinnati syndicate and is located near the mouth of Alexander creek. The property has not been worked since 1909 but preparations are under way to open it up again.

Extensive gravels occur in the bottom and sides of the valley and apparently were deposited at the close of Glacial time by a large river with a low gradient. The present small stream has cut down to bed-rock through these gravels. The gravels consist of clean sands and well rounded water-worn pebbles of small sizes. The bed-rock is quartzite and argillite and forms a very irregular floor. The distribution of gold in the gravels and the value per cubic yard is not known.

The water is taken from 2 miles up Alexander creek and operates two 7-inch giants under a head of 340 feet. A sluiceway 2,000 feet long has been constructed to carry the tailings beyond a flat stretch of the creek.

Eldorado Mining Company.

This company has 1½ miles of upper Eldorado creek under lease for placer ground. At the time of examination the ground was being prospected to ascertain the advisability of installing an hydraulic plant.

The gravels consist of sands and boulders up to 2½ feet in diameter and contain a certain amount of clay. They occur in the creek bottom and along the sides of the creek. The thickness of the gravel varies from 2 to 12 feet. The gold is all fine and some pieces are quite angular.

As the property is located near the head-waters of the creek where the stream is small there has not been sufficient opportunity for the water to work over the gravels and produce a concentration of the locally derived gold, nor for the accumulation of extensive gravels.

COAL.

On the north side of Bridge River valley near Jones' ranch, at an elevation of 1,800 feet above the river, a group of coal claims have been staked by W. W. Jones, of Lillooet. The claims have been held for some time but no work of any extent has been done.

The rocks here consist of a series of volcanic tuffs, breccias, and andesitic lavas. Interbedded with them are soft weathering shales, sandstones, and conglomerates.

The conglomerates are made up of well rounded pebbles of cherty quartzite which are derived from the quartzites of the Cache Creek series. The beds have an east and west strike and dip at low angles to the north. They rest unconformably on the Cache Creek rocks and are thought to be of Tertiary age.

A few thin seams of lignite coal occur in the shales. It is a high grade lignite but the seams are narrow, less than 6 inches, lens shaped, and not continuous. Furthermore the coal series is confined to a small area and is much broken up by volcanic intrusives so that even if larger seams are found their extent would not be sufficient to be of commercial importance.

THE GEOLOGY OF CERTAIN PORTIONS OF YALE DISTRICT, B.C.

(*Charles Camsell*)

Introductory Statement.

The work of the field season of 1912 covered certain mineralized portions of Yale district and adjacent parts of southwestern British Columbia. This work included an examination of gold-copper deposits at Kruger mountain in Okanagan valley; a brief study of Tertiary coal bearing rocks at White Lake in Okanagan valley; a reconnaissance of the mineralized belt on the range of mountains lying between Keremeos creek and Twentymile creek; and a brief examination of the copper deposits of Copper mountain, near Princeton, where development work by the British Columbia Copper Company had been in progress for a year. In addition, some time was devoted to the supervision of the work being carried on by A. M. Bateman in the Lillooet district and by N. L. Bowen on Fraser river, and other duties.

The Copper Deposits of Kruger Mountain.

TOPOGRAPHY.

Kruger mountain is situated in the Interior Plateau region, on the western side of Okanagan valley, at the International Boundary line. It occupies the angle between Okanagan valley and the Similkameen river. It is an irregular, almost flat-topped mountain rising easily to a height of about 3,000 feet above Osoyoos lake or about 4,000 feet above sea-level. In general character Kruger mountain is not greatly different from the rest of the Interior Plateau region, except that it forms a long ridge broadening to the north, separated from the surrounding region by the deep Okanagan valley on the one side and the equally deep Similkameen valley on the other. These two valleys have been entrenched in the surface of the Interior Plateau region leaving the Kruger Mountain block as an upstanding remnant between them. It is, therefore, a full-bodied mountain retaining the general topographic features characteristic of the greater part of the Interior Plateau region. It slopes easily down on the east to the level of Osoyoos lake, but more sharply on the west to the Similkameen river.

The lower slopes of the mountain are grass covered and quite devoid of any trees. On the summit, however, is an open forest growth of large yellow pine and fir.

GEOLOGY.

The oldest rocks of Kruger mountain consist of a highly disturbed and metamorphic series of stratified rocks which include micaceous quartzites, schists, greenstones, and some lenses of limestone. The series has been metamorphosed not only by regional action, but also by contact action resulting from the intrusion of adjacent batholithic igneous bodies. These rocks have a general east and west strike, and have been faulted in several directions. One of the strongest lines of faulting runs almost north and south. The limestone lenses are economically the most important members of the series, and in the neighbourhood of the larger intrusive rock bodies have been altered and silicified to the characteristic lime-

silicate rock consisting of garnet, epidote, pyroxene, hornblende, quartz, and some calcite. In places these lenses of limestone have escaped silicification and have merely been rendered crystalline. The series has been called by Daly the Anarchist series and has been correlated with Dawson's Cache Creek (Carboniferous) series. These rocks hold the ore deposits.

To the north, the Anarchist series has been intruded by a batholithic body of granodiorite (the Osoyoos batholith), a medium-grained, greyish rock consisting of both orthoclase and plagioclase, hornblende, biotite, and some quartz. Apophyses of this rock penetrate the Anarchist series in all directions, and these, together with the main body, are responsible for the alteration of the stratified rocks and probably for their mineralization as well.

On the south and west sides of Kruger mountain an alkaline plutonic body, younger than the Osoyoos batholith, penetrates the stratified rocks. Other igneous rocks are dark coloured dykes of diabase and lamprophyre.

Immediately to the south of the International Boundary line the Anarchist series is covered by a small area of Tertiary rocks consisting of conglomerate, sandstone, shale, and some volcanic material. These rocks are probably Oligocene in age and may be correlated with the rocks of the interior Tertiary lake basins of British Columbia.

ORE DEPOSITS.

Considerable prospecting and development have been done within the last fifteen years on the lode deposits of Kruger mountain on both sides of the International Boundary, but more especially on the United States side. A detailed description of the deposits on the south side of the line is given by J. B. Umpleby in Bulletin No. 5, Part II, of the Washington Geological Survey. These deposits are of two kinds , namely, disseminated copper deposits, and vein deposits carrying gold as the principal valuable metal. The latter are the more important and are responsible for the whole lode metal production of the district.

The ore deposits on the Canadian side are mainly of the first type mentioned, namely, disseminated deposits carrying copper with some gold. These are situated in close proximity to the granodiorite and are probably genetically connected with it.

The examination of these deposits was confined to a limited area covered by a group of claims owned by the Gold Dust Mining Company and the Dividend-Lakeview Mining Company. These claims are situated on the eastern slope of Kruger mountain about one mile north of the International Boundary line, and at an elevation ranging from 300 to 1100 feet above Osoyoos lake.

The country rocks of this area include greenstones, green schists, and lenses of limestone. The ore deposits are restricted to the limestone, and are situated at no great distance from the contact of the granodiorite. They appear to be genetically connected with the intrusion of the granodiorite and have all the characteristics of deposits of contact metamorphic origin.

The gangue of the ores is the limestone which, however, has usually been altered to a lime-silicate rock containing garnet, epidote, calcite, pyroxene, and hornblende. The metallic minerals are pyrite, pyrrhotite, chalcopyrite, arsenopyrite, and magnetite. Of these, pyrite and pyrrhotite are present in all or most of the deposits; arsenopyrite is abundant in the Dividend workings; while chalcopyrite is most plentiful in the workings of the Lakeview. The deposits contain gold and copper as the chief valuable metals, and since the gold content is higher on the Dividend than the other claims it seems likely that, as in adjacent districts, the gold is associated with the arsenopyrite.

As in most deposits of this origin the ore bodies have no well defined boundaries, but pass by a gradual transition into low grade ore and out into barren rock. So far as present development has gone, workable ore appears to be confined to the altered limestone so that the direction of the ore-shoots should be controlled by the dip and strike of the limestone. Faulting, however, has taken place subsequent to the deposition of the ore, and in the progress of development this fact should constantly be borne in mind, and the direction and displacement of such faults carefully studied.

Oxidation has in general not gone deeper than a few feet, producing a capping of limonite and carbonates from which free gold can often be obtained by panning. On the Lakeview claim, however, oxidation of the ore is apparent to a depth of 100 feet below the surface.

Development.—The development work on the area has been done mainly on the Gold Dust, Lakeview, and Dividend claims, and consists of a number of shallow pits and some underground work.

The workings on the Gold Dust are not extensive and include open-cuts and shallow test pits. An adit tunnel, 150 feet in length, driven into the side of the mountain, is entirely in schist and has not yet cut the ore which is supposed to extend down from the surface.

On the Lakeview the underground workings, consisting of tunnels, drifts, and shafts, aggregate several hundred feet, the result of which has been to expose an ore body of unknown but considerable size, striking east and west and dipping towards the north. Copper is the principal valuable metal in the ore, which is stated to have a maximum total value of $24 to the ton in all metals.

The main workings on the Dividend are two tunnels, one 150 feet below the other connected by a raise. The ore body as cut in the upper tunnel has a maximum width of nearly 20 feet, but narrows down at a depth of 50 feet below. It strikes east and west and dips to the north at an angle of 60°. The lower tunnel follows a vertical fault plane, which strikes north and south, and has a downthrow to the west. The fault probably also cuts the ore body but the contact has not been exposed in the workings. A quantity of ore on the dump of the upper tunnel is stated to have a value of $20 to the ton, chiefly in gold.

White Lake Coal Area.

INTRODUCTION.

White Lake is a small post-office situated on the western side of Okanagan valley about 6 miles west of Okanagan Falls. It lies in an area of coal-bearing rocks which has for convenience been named the White Lake Coal area. The area of the field is about 6 square miles and it occupies the northern part of township 53 of the Similkameen Land Division.

The value of the field as a possible producer of coal is doubtful and has not yet been determined. Some mining of coal has, however, been done from a narrow seam near the centre of the basin, and the coal extracted used for blacksmithing purposes at Fairview when quartz mining was being carried on at that point.

No geological work had previously been done on this area, but a small collection of fossil plants was made by the author in 1910 from an outcrop of shale and sandstone, and this collection has been sufficient to determine the age of the coal-bearing formation.

TOPOGRAPHY.

White Lake Coal area is a basin-shaped depression almost completely sur-

rounded by hills which rise more or less steeply from its central part. A small lake, known as White lake, which has no outlet, lies almost in the centre of the area, and from this the slopes rise on all sides. To the west the slopes rise high and steep but not irregularly, to the summits of the range which forms the divide between Okanagan valley and Keremeos creek. On the east the slopes are not as high but are more broken, and in this direction an exceedingly rough and broken country consisting of a jumble of steep hills and depressions, separates the coal area from Okanagan valley. This broken country is probably the locus of an ancient volcano which was active about the time that the coal-bearing formation was being deposited.

Two streams, each of them dry during the latter part of the summer, traverse the coal field. Park rill enters the field from the west and flows out by a narrow valley at the south. Prather creek enters from the north and leaves by a narrow inconspicuous gorge which cuts through the broken country southeast of the coal field. White lake has no outlet, and this, with other small ponds in its neighbourhood, appears to be fed from springs. There are several springs in this neighbourhood, some of which are sulphurous and possibly represent the last stages of expiring vulcanism.

All the central and lower parts of the area are open and free from any growth of timber. Higher up the slopes, however, and covering the summits of the bordering hills, is an open forest of pine, fir, and poplar. The whole area of the coal field was at one time an excellent grazing ground for horses and cattle, but so many cattle have been allowed to range over it that the grass which formerly covered it is being replaced by sage brush. The climate of White lake is dry and mild and if water for irrigating purposes could be obtained it might be made to produce a variety of fruits.

GEOLOGY.

No rocks older than Tertiary are exposed in or around the White Lake area, but some cherty quartzites associated with argillites, probably Palæozoic, outcrop in the valley of Park rill south of the area. Angular fragments of these rocks are also included in the volcanic agglomerates and tuffs which overlie the coal-bearing rocks, indicating that a basement of these Palæozoic rocks underlies the Tertiary rocks, fragments of which were rifted off the walls of vents during outbursts of vulcanism.

Underlying the coal-bearing rocks is a series of volcanic flows of basic or medium basic composition, consisting of basalts and porphyrites. This series appears to lie in conformable relation to the coal-bearing rocks and, from the attitude and general character of its beds, is of Tertiary age.

The coal-bearing rocks cover an area of about 6 square miles in the northern part of township 53, and occupy almost all of sections 27, 28, 29, 33, 34, and 35, and small parts of adjoining sections. They consist of tufaceous sandstones and true tuffs, shales, conglomerate, breccia, and thin seams of coal.

A section along the valley of Prather creek on the north side of the basin was measured which gave a thickness of about 2000 feet of beds. It is very likely, however, that this thickness is not uniform throughout the whole area, but, because of the conditions under which the beds were deposited, must vary greatly from one side of the area to the other. It is possible also that the 2000 feet of thickness in the section represents more than the actual thickness of the beds, for while there is no apparent duplication of the beds by faulting it is very probable that there has been some slipping or faulting along the planes of bedding so as to give the section an apparent thickness greater than the actual.

A study of the measured section shows that the whole series can roughly be divided on lithological grounds into three parts. The lowest third of the section contains a preponderance of black and grey shales with a minor amount of sandstone. The shales are associated in places with thin seams of coal. The middle third contains chiefly sandstones with some bands of grey shales. The uppermost third consists wholly of tufaceous sandstones.

In the central portion of the area some grey shales and two narrow seams of coal outcrop. These beds are not contained in the section measured, and probably overlie it and constitute the topmost members of the series.

The sandstones are all grey in colour and vary in the coarseness and angularity of the grains from the east to the west side of the area. On the east the grains are more rounded and water-worn while on the west they are very angular, showing a proximity to their original source.

The coal seams are all small, and none of those so far exposed are of much commercial importance. On the north side of the area in the valley of Prather creek a seam 3 feet in thickness has been exposed in an incline shaft about 45 feet deep. The seam, however, contains so many partings and bands of clay that it is of little commercial value. About 100 feet east of this point a vertical shaft 50 feet in depth is said to have cut a bed, 9 feet in thickness, of coal and shale. The section on Prather creek shows that both above and below the two seams exposed in the shafts are other thin bands of coal, all, however, of small size and of no commercial importance.

So far as at present known the most important seams of coal are those exposed in a small ravine on the northwest side of White lake. These seams are respectively 14 and 20 inches in thickness. A shaft 35 feet in depth was sunk some years ago on the coal seams and about 1000 tons of coal mined. This coal is of a bituminous character and was used at Fairview for blacksmithing purposes.

In general the structure of the White Lake Coal area is that of a synclinal basin, the strike of which is east and west. In detail, however, there are often wide variations from this direction, especially on the eastern side of the area where apparently there has been considerable disturbance since the deposition of the coal-bearing beds. The dips range 0° to 50° and average about 30°. Some faulting has taken place, especially in the disturbed region on the east.

The rocks of the coal-bearing formation appear to have been laid down in a gradually subsiding basin on the western edge of the region in which vulcanism was active at intervals throughout the whole period of their deposition. The eruptions at this focus were of the explosive type and great volumes of tuff were blown out and deposited in the basin. In parts of the basin these tuffs were water-worn to form true sandstones, but in other parts they have not been so worn and they retain the same angularity of grain that they had when first ejected.

Both the sandstones and shales contain a great many plant remains, and from a very small collection of these the age of the rocks was determined as Oligocene. They are, therefore, correlated with other areas of coal-bearing rocks at Princeton, Nicola, Tulameen, and other points in the southern interior of British Columbia.

Overlying the coal-bearing rocks on the east is a series of volcanic breccias and tuffs and some flows of an andesitic or more acid nature. In places the overlying volcanic rocks succeed the coal-bearing rocks conformably, but in other places there is a marked angular unconformity between them. It is probable, however, that this unconformity does not indicate any great time interval between the two series. The upper volcanic rocks occupy an exceedingly irregular and broken country to the east of the coal basin, which no doubt is the source from which tuffs were derived. This broken country is apparently the locus of an ancient Tertiary volcano which was active at intervals during and after the deposition of the coal-bearing rocks. It has all the characteristics of an ancient, denuded

volcanic crater about a mile in diameter, the bottom and sides of which have slumped in, leaving a series of steepsided hill and deep sinkholes now often filled with water.

THE VALUE OF THE COAL AREA

From the evidence that has been obtained which consists merely of an examination of the surface, it is not possible to make any definite statement relative to the actual or probable value of the field. Small coal seams occur both at the top and bottom of the series. The two seams at the top are small but contain a good grade of clean coal and some mining has been done on them. Those at the bottom are larger but where they outcrop at the surface are too dirty to make a useful fuel. Their dirty character may be due to proximity to the border of the basin and it is possible that they may become cleaner towards the centre of the field. This, however, can only be determined by putting down a bore-hole which, in the centre of the field, would have to be driven about 1,500 feet in depth to intersect the seams.

Independence Mountain.

INTRODUCTION

Independence mountain, with Riordan, Stevenson, Dividend, and other adjoining mountains, forms that part of the Okanagan range situated north of Similkameen river between Keremeos creek and Twentymile creek in Osoyoos Mining division. The range here has a north and south trend and to the south is separated from the main part of the range by the deep valley of Similkameen river. The range is characterized by rounded summits, with gentle slopes to the west and more precipitous slopes to the east. Its highest point is Independence mountain which has an elevation of 7,360 feet above sea-level as obtained by aneroid, and is the only point that reaches above the timber line. The whole of this part of the range is below the upper limit of continental glaciation, which probably reached in this region an elevation of 7,500 feet above sea-level.

The eastern slopes of the range are drained by short swift streams flowing into Keremeos creek, while the drainage on the west is by Twentymile, Sixteenmile, and Fifteenmile creeks all emptying directly into the Similkameen river.

The summit of the range may be reached by trails from Keremeos and Sixteenmile creeks, and a good wagon road connecting Penticton with the Nickel Plate mine and Hedley, crosses a pass at Riordan mountain. From this wagon road a branch road runs south to the Apex group.

GEOLOGY

The country rocks in the vicinity of Independence mountain are limestones, quartzites, and argillites, all highly metamorphosed and considerably disturbed. They strike in general northeast and southwest and dip at high angles. They are similar in structure and lithological characters to the rocks of Nickel Plate mountain which lies across a wide valley to the west, and are evidently of the same age, namely Palæozoic (Carboniferous?).

The Palæozoic rocks are intruded in a great many places by dykes, sills and irregular bodies of diorite, diorite porphyrite, andesite and granite porphyry, and to the north of Riordan mountain by a batholithic body of granite. These igneous rocks have produced contact metamorphism in the stratified rocks, altering the limestones especially to a rock consisting of the lime-silicate minerals, garnet, epidote, pyroxene, and hornblende.

The mineral deposits are all contained in the stratified rocks, especially the altered limestones, and are apparently genetically connected with the intrusion of the diorite and diorite porphyrite. They are mainly of the contact metamorphic type and contain copper as the principal valuable metal, with always some gold and a little silver. The metallic minerals present are pyrite, pyrrhotite, chalcopyrite, magnetite, and sometimes arsenopyrite, and the gangue is usually calcite or the minerals formed from the alteration of limestone. It is worthy of note that wherever arsenopyrite is present in the ore the gold content increases. As is usual in deposits of this character these deposits are of irregular shape and have usually no well-defined walls. They are all of low grade, but some of them large.

MINERAL CLAIMS

A great part of the range within a radius of several miles from Independence mountain is covered by mineral claims, many of which have been held for about fifteen years and some of which are surveyed and Crown granted. Those claims which were in existence in 1901 were examined by W. F. Robertson, Provincial Mineralogist for British Columbia, and described in the Annual Report of the Minister of Mines for that year. Interest in this district has waned within recent years and little work has been done. For this reason and because of the lateness of the season at which the visit was made, it was not possible to find all the workings and, in consequence, some of the groups of claims are omitted from this description.

The Apex group is at present the best known group of claims in this district and has had the most work done on it. It includes six claims which are situated on an eastern spur of Independence mountain, the main workings being at an elevation of 6,950 feet (aneroid) above sea-level. The rocks at the upper workings consist of blue limestone interbedded with cherty quartzite and cut by fine-grained diorite porphyrite. The strata strike N. 60° E. and dip 55° to the southeast. The ore consists mainly of pyrrhotite and arsenopyrite in a gangue of coarsely crystalline limestone and occurs in bunches or ill-defined veins. This deposit has been prospected by an inclined shaft 120 feet deep and about 200 feet of drifts. At the lower workings a tunnel 120 feet in length cuts diagonally across a body of ore about 20 feet in width, which consists of pyrrhotite, pyrite, and chalcopyrite in a gangue of calcite and garnet.

The Billy Goat group is situated on Riordan mountain, which has an elevation of 6,950 feet above sea-level. The country rock is highly metamorphosed limestone cut by dykes and irregular bodies of diorite and diorite porphyrite. The deposits contain mainly copper and are of contact metamorphic origin. They are situated on the contacts of the diorite and diorite porphyrite and contain pyrrhotite, pyrite, chalcopyrite in a gangue of garnet, epidote, calcite, and quartz. The bodies are of irregular outline but are of large size. Assays, however, show them to be low grade. The deposits have been exposed in a number of open-cuts.

The Black Hawk group consists of nine claims situated on both sides of Cedar creek, a tributary of Keremeos creek, at an elevation of 5,400 feet (aneroid) above sea-level and about 6 miles from Keremeos. The workings consist of a tunnel 164 feet and a hole 20 feet in depth and about 12 feet wide. The rocks are limestones and quartzites cut by a light coloured andesite dyke and by granite porphyry. The ore body, which in the tunnel is 8 feet wide and in the hole 12 feet, is a replacement of the limestone and contains pyrite, chalcopyrite, magnetite, and some arsenopyrite. It appears to follow the dip and strike of the limestone and has more definite outlines than the deposits previously described. The ore is said to carry copper, gold, and silver.

Other groups of claims were examined in this district, namely, the Dividend, Beaconsfield, and McEachran groups, but all of them are of similar character to one or the other of the three groups described.

Copper Mountain.

INTRODUCTION

Copper mountain is a mineralized district situated on the east side of the Similkameen river about 10 miles south of the town of Princeton. A brief preliminary examination of this field was made in the summer of 1906 and a report of it is contained in the Report No. 986 of the Geological Survey, Preliminary Report on a Part of the Similkameen District.

For several years previous to 1906, prospecting and development work in this district were actively carried on, but since that time it has remained dormant and because most of the claims are Crown-granted, owners have not been obliged to do even the annual assessment work. In 1911, however, interest was revived by the entry into the district of the British Columbia Copper Company who took options on and have been exploring a large group of claims situated on both sides of Wolf creek. This work has been actively carried on by a large staff of men both by sinking and drifting on the ore bodies and by the use of diamond drills.

The Copper Mountain district lies in, and has the characteristic topographic features of, the Interior Plateau region. It is a round-topped, wooded mountain sloping steeply westward to the deep canyon-like valley of Similkameen river and cut into on the east by the broad flaring valley of Wolf creek. At the north end is Smelter lake, a deep, narrow lake about 1½ miles long and a few hundred feet in width. The highest point in the district is Copper mountain itself which has an altitude of nearly 4,500 feet above sea-level. Points immediately to the east, however, reach greater elevations. The lowest point is the bed of Similkameen river to the west of the mountain, which has an altitude of 2,600 feet. The vertical relief is, therefore, about 1,900 feet. The whole district is covered by an open forest growth of fir, spruce, and pine, and a great part of it is drift-covered so that much of the surface prospecting has to be done by trenching and sinking pits.

Voight's Camp, which is situated on Wolf creek and is the central point of the district, is connected with Princeton by a good wagon road 12 miles in length.

GEOLOGY

The country rock of Copper mountain is a stock of monzonite which has been intruded into Palæozoic sedimentary rocks, remnants of which are now found as highly altered inclusions in the monzonite. Overlying the monzonite is a series of volcanic flows of Tertiary age which are found on the northern slope of the mountain.

The monzonite is a fine- to medium-grained, tough rock of very variable composition and colour. It includes at least two types of rocks which were irrupted at quite different though not widely separated periods. The prevailing type is the more basic one and contains both plagioclase and orthoclase, augite and some biotite. Hornblende is also present but probably as an alteration from augite. Pyrite and magnetite are present as accessory constituents, and chalcopyrite and bornite are primary constituents of some of the pegmatitic phases of the rock. Variants of this rock contain the augite without any biotite. The texture is granitic but a porphyritic habit is occasionally developed. The more acid type is lighter in colour and contains more orthoclase and biotite in proportion to the other minerals.

The monzonite is traversed by a number of pegmatite veins, apparently emanations from the same magma, which contain large crystals of pink feldspar, biotite, and calcite. In some veins the calcite is absent but in others it is the only mineral present. Chalcopyrite is often present in these veins when it appears intergrown with the feldspar, and bornite had also been noted in the same relationship. The presence of the sulphides in the pegmatites suggests that the monzonite magma was comparatively rich in copper and was very probably the source of the copper of the ore deposits.

Because of its tough, close-grained character the monzonite frequently shows no well-defined system of jointing or fracture. The best defined joint planes are those which strike N. 60° E. and S. 50° E. Fracturing has taken place in two major directions, namely S. 80° E. and S. 10° W. Both of these directions coincide with the strike of some of the ore bodies, while the latter is the direction of strike of most of the dykes which cut the monzonite. Faulting has taken place to a considerable extent throughout the whole district but the displacement is usually not great. In appears to have both preceded and followed ore deposition, so that some of the ore bodies follow the lines of fracturing and faulting while others are cut off and displaced by them.

Dykes of granite porphyry, syenite porphyry, quartz porphyry, and diabase traverse the monzonite, striking in a direction almost north and south. A majority of the granite porphyry dykes outcrop on the east side of Wolf creek and many have been encountered underground that do not reach the surface. Some are as much as 150 feet in width. They show chilling and flow structure on their borders and are porphyritic or almost granitic in the centre. The diabase is fine grained and soft, and later in date than the intrusion of the porphyries.

The monzonite is overlaid to the north by extrusive rocks of Tertiary age consisting of andesites, basalts, and some rhyolite. These rocks are associated with and somewhat younger than the coal-bearing Oligocene rocks centreing about Princeton. They appear to have covered a great part of Copper mountain previous to the Glacial period, and it is due to the protecting cover of these lavas that there is such a depth of decomposed monzonite now remaining on parts of the mountain.

ORE DEPOSITS

In the brief time spent at Copper mountain no attempt was made to make a detailed study of the occurrence of the ore deposits as a whole, but the examinations were confined to the mineral claims on which development was being carried on. If this development proves that the ore bodies are of sufficient size and value to be worth mining for their metallic contents, it will be necessary to conduct more detailed topographic and geological surveys of the district in order to determine the origin, mode of occurrence, and general relationships.

The principal mineral claims on which work was being done are the Silver Dollar, Red Eagle, Ada B, and Triangle on the west side of Wolf creek, and the No. 14 and adjoining claims on the east side of the creek.

The ore body on the No. 14 claim lies in monzonite on the eastern side of a large quartz porphyry dyke which strikes north and south. The ore body, at a depth of 90 feet below the surface, strikes east and has a known length of 150 feet and a maximum width of 80 feet. It lies in a zone of fracture and appears to be a replacement deposit which was formed under conditions of high pressure and temperature. The ore minerals are hematite, pyrite, and chalcopyrite in a gangue of calcite and altered monzonite. The ore contains copper and a higher proportion of gold than is usually found in the other deposits of this district.

On the western side of Wolf creek, development was being prosecuted, par-

ticularly on the Silver Dollar, Ada B, and adjoining claims. On the Ada B, the ore body contains pyrite, magnetite, and some chalcopyrite disseminated through the monzonite, which has a brecciated character. On the Silver Dollar the ore lies in a broad north and south zone of monzonite which has been highly altered and whitened by mineralizing solutions. The metallic minerals in this zone are chalcopyrite in small veinlets, bornite in individual grains, and occasionally some arsenopyrite and galena. Chalcopyrite and pyrite also impregnate the country rock on either side of the zone of alteration. Pegmatitic phases of the monzonite are common in this locality. These contain large crystals of feldspar, biotite, calcite and frequently chalcopyrite and sometimes bornite. Certain specimens show the chalcopyrite in large individuals intergrown with the feldspar and evidently of contemporaneous origin. The mineralized area on these claims is very large and appears to strike slightly west of south. The value of the metallic content, however, is much lower than in the deposits on the east side of Wolf creek.

In other deposits to the northeast of the Silver Dollar, magnetite is the most abundant metallic mineral and in certain zones of brecciation in the monzonite, it forms the cement which binds the brecciated fragments together. The value of this class of deposits is, however, low.

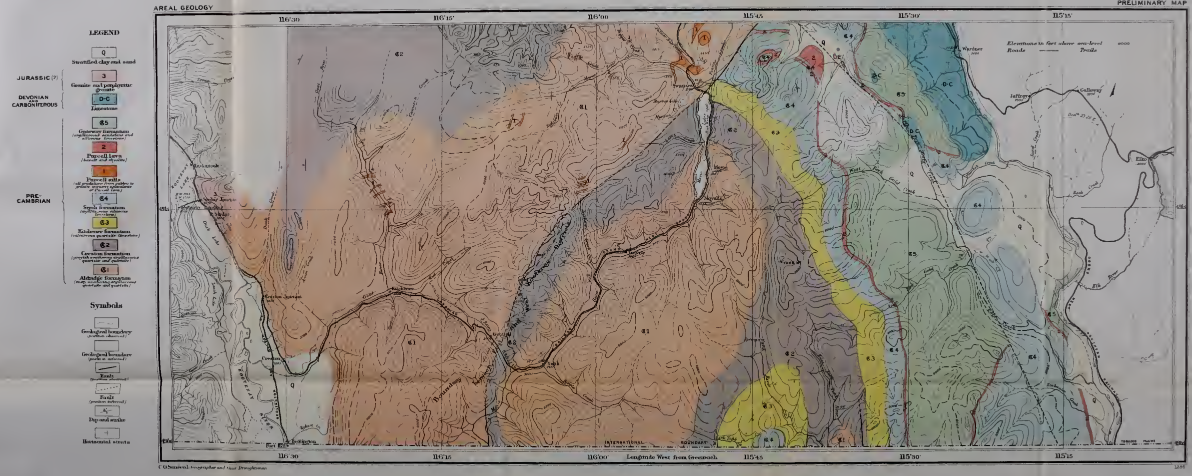
From a study of these occurrences it seems clear that the primary source of the copper is in the monzonite itself. The presence of chalcopyrite and bornite in pegmatite veins intergrown with feldspar and biotite indicates that the magma was rich in copper. These veins, however, do not form commercial ore deposits. The workable ore bodies seem to lie in zones of fracture which strike on the east side of Wolf creek in an east and west direction and on the west side of Wolf creek in an almost north and south direction. Mineral solutions ascending through these zones of fracture have altered and replaced the monzonite and deposited the copper and gold-bearing minerals in them and in the adjacent wall rock. Most, though perhaps not all of the mineralization was accomplished before the injection of the granite porphyry and quartz porphyry dykes and was followed by some faulting and displacement.

Canada
Department of Mines

HON. L. CODERRE, MINISTER. A. P. LOW, DEPUTY MINISTER.

GEOLOGICAL SURVEY

R. W. BROCK, DIRECTOR



MAP 89 A
(Issued 1913)

SOUTHERN PORTION OF CRANBROOK MAP-AREA, EAST AND WEST KOOTENAY, BRITISH COLUMBIA.

Scale of Miles
2 1 0 2 4 6 8 10

To accompany Summary Report by S. J. Schofield, 1912

Sources of Information
Geology by S. J. Schofield 1911-1912.
Topography from published map by the Geological Survey

RECONNAISSANCE IN EAST KOOTENAY, BRITISH COLUMBIA

(Stuart J. Schofield.)

Introduction.

During the field season of 1912, the writer pursued geological investigations in an area of East Kootenay, B. C., south of Cranbrook. The area lies between the Canadian Pacific railway (Crowsnest branch) and the International Boundary line, from Kootenay river westward to Kootenay lake.

Mr. P. P. Baily rendered efficient aid as geological assistant.

General Geology.

Tabular Description of Formations.

Pleistocene and Recent		Unconsolidated gravel and sand, lignite.
	Unconformity.	
Jurassic?		Dyke intrusion: aplite, lamprophyre, and porphyritic granite.
	Kootenay granite	Granite and porphyritic granite.
Mississippian	Wardner limestone	Grey limestone. Thickness, 1,000+feet.
Devonian		Limestone and shale. Thickness, 500+ft.
Pre-Cambrian (Purcell series)	Roosville formation	Green siliceous argillite. Thickness, 600 ft. (Daly).
	Phillips	Purplish-red and green siliceous argillite and sandstone. Thickness, 550 ft. (Daly).
	Gateway formation	Light grey quartzite, siliceous dolomite and limestone. Thickness, 2,025 ft. (Daly).
	Purcell lava	Amygdaloidal basalt. Thickness, 300 feet.
	Siyeh formation	Thin-bedded green and purple mud cracked shale; some limestone. Thickness, 4,000 ft. (Daly).
	Kitchener	Thin-bedded dark grey argillaceous quartzite and limestone. Thickness, 4,500 ft.
	Creston	Light grey argillaceous quartzite and purer quartzite. Thickness, 5,000 ft.
	Aldridge formation	Rusty weathering heavy and thin-bedded argillaceous quartzite and slate. Numerous sills of gabbro at various horizons. Thickness, 8,000$\pm$ft.=1,830 m.

CHANGES IN STRATIGRAPHICAL CLASSIFICATION

In 1911, Daly identified the Kitchener and Creston formations for the writer in the neighbourhood of Kingsgate, B. C., and upon this identification the formations in East Kootenay were named. Subsequent work by the writer in 1911, definitely proved that the so-called Kitchener rocks near Kingsgate were older and not younger than the Creston, and consequently could not be Kitchener and, therefore, the name Aldridge formation is now proposed for the group of rocks below the Creston.

The name Kitchener was tentatively dropped in the stratigraphic series of East Kootenay until the rest of Daly's stratigraphic series was examined[1].

[1] S. J. Schofield, Geol. Surv., Can., Summary Report, 1911, p. 159.

This was done during the past season of 1912 and the Kitchener formation was found to overlie the Creston as Daly has found, thus proving that the Aldridge formation in the neighbourhood of Kingsgate could not be, as supposed by Daly, a western phase of the Kitchener as developed about Yahk river . Because of the above-mentioned misidentification of the Kitchener, the Creston formation in previous work in East Kootenay included the Kitchener rocks.

The rocks forming the great McKim cliff overlooking the Kootenay river north of Post Hill were identified by Daly as being Creston. These same rocks were crossed along the Canadian Pacific railway from Kitchener to Creston and there proved to belong to the Aldridge formation. Calkins has identified these same rocks as Pritchard which are correlated with the Aldridge. The rocks of the McKim cliff are evidently Aldridge and not Creston; this correlation is also supported by the presence of numerous thick gabbro sills.

Further study was devoted to the Moyie formation as outlined by Daly, west of Kingsgate. Lithologically they belong to the Aldridge formation and they rest conformably upon the same rocks which Daly identified as Kitchener near Kingsgate, but which were subsequently proved to belong to the Aldridge formation. Hence they cannot be Moyie which as originally defined by Daly, lies conformably upon the Kitchener. The writer believes them to be an argillaceous phase of the Aldridge.

The Moyie, as defined by Daly in the vicinity of the Yahk river, rests upon the Kitchener formation conformably. In this region the so-called Moyie consists of green and purple mud-cracked shales and argillites and strongly resembles the Siyeh formation. It occupies the same stratigraphic position as the Siyeh south of Cranbrook, which there overlies the Kitchener and underlies the Purcell lava. The Purcell lava is absent in the boundary section. Daly states that the Purcell lava is absent between the Kitchener and so-called Moyie on the International Boundary line because the flow did not extend as far west as the Yahk river. The writer believes the lava occupied a position above the so-called Moyie and has been removed by erosion. The writer concludes that the so-called Moyie in the neighbourhood of Yahk river is equivalent to the Siyeh. Hence the name Moyie has been dropped from the stratigraphical series of East Kootenay

CORRELATION OF PURCELL SERIES

The following correlation of the Purcell series of East Kootenay, B. C., with those of the Coeur d'Alene district and northern Idaho, is based upon lithological characters. The Coeur d'Alene district was visited and the formations there exposed were carefully studied. In addition, Calkins' areal map along the International Boundary line was compared with the writer's map of the same region in the light of the new discoveries in the stratigraphy and structure of the Purcell series, made in the last two years.

Coeur d'Alene District, Idaho. (Calkins)[1]			*East Kootenay District, B.C.* (Schofield)	
Striped Peak,	1,000 feet +		Siyeh,	4,000 feet.
Wallace,	4,000 "		Kitchener,	4,500 "
St. Regis,	1,000 "	} 4,200 feet	Creston,	4,000 "
Revett,	1,200 "			
Burke,	2,000 "			
Prichard,	8,000 "	+	Aldridge,	8,000± "

[1] F. L. Ransome and F. C. Calkins, U. S. Geol. Surv., Prof. Paper, 62.

A correlation between the formations of East Kootenay and the Coeur d'Alenes was made in 1909 by Calkins[1]. At that time the Aldridge formation had not been differentiated from the Kitchener formation in the Purcell series. Hence some difference in the correlation would naturally arise.

Coeur d'Alene District, Idaho. (Calkins)[2]		*East Kootenay District, B.C.* (Daly)[3]
Striped Peak, 1,000 feet +		Yahk, 500 feet.
Wallace, 4,000 "		Moyie, 3,400 "
St. Regis, 1,000 "	4,200 ft.	Kitchener, 7,400 ft.
Revett, 1,200 "		
Burke, 2,000 "		
Prichard, 8,000 " +		Creston, 9,500 ft.

Daly, in a forth-coming memoir of the Geological Survey, Canada, proposes the following correlation. Since Daly's field work was done in 1904, his correlation is affected like Calkins by the misconception of the stratigraphy of the Purcell series.

Coeur d'Alene District, Idaho. (Calkins)[4]	*East Kootenay District, B.C.* (Daly)[5]
Striped Peak, 1,000 feet	Moyie, 3,500+feet.
Wallace, 4,000 "; St. Regis, 1,000 "	Kitchener (upper part), 6,000±ft.
Revett, 1,200 "; Burke, 2,000 "; Prichard, upper part, 1,500 ft.	Kitchener (lower part), 1,400±ft.; Creston (upper part), 1,400±ft.
Prichard, lower " 6,500 ft.	Creston (lower part), 6,500+ft.

PURCELL SERIES

General Description

The rocks of the Purcell range form the western part of the ancient group of sediments deposited in the Rocky Mountain geosyncline. These sediments, called the Purcell series, of Pre-Cambrian age, consist of a great thickness of fine-grained quartzites, argillaceous quartzites, argillites, and limestones. At various horizons in the above series, shallow water characteristics, including ripple marks, mud cracks, and casts of salt crystals, are very common. The Purcell series extends across the International Boundary line into Idaho, and Montana, while to the north geological exploration has, up to this time, been insufficient for the exact determination of this series in that direction. To the west, on account of batholithic intrusions, the relations are not very clear, but there is sufficient evidence to prove the existence of numerous patches of 'Archæan' schists on the slopes of the Purcell trench (Kootenay Lake valley). This ancient acidic terrane probably represents at least part of the old land from which the quartzitic Purcell series was derived. The stratified members of the Purcell range pass under the younger formations of the Rocky mountains to the east.

[1] F. C. Calkins and D. F. MacDonald, U. S. Geol. Surv.. Bull. 384, p. 41.
[2] F. L. Ransome and F. C. Calkins, U.S. Geol. Surv., Prof. Paper, 62.
[3] R. A. Daly, Geol. Sur. of Can., Summary Reports 1904 and 1905.
[4] F. L. Ransome and F. C. Calkins, U.S. Geol. Surv., Prof. Paper 62.
[5] R. A. Daly, Geol. Surv., of Can., Summary Report, 1904 and 1905.

The small cross-cutting bodies of granite and porphyritic granite, which intrude the Purcell series, are considered to be small cupola-like stocks, bearing a genetic relationship to the great Nelson granite batholith.

The age, subdivision, and correlation of the great thickness of sedimentary strata, exposed in the Purcell range, have been the subject of much study during the last few years. The sedimentary series of East Kootenay forms a part of this greatly discussed series. Since no fossils have as yet been discovered in the Purcell series, the subdivision into formations is based solely on physical and lithological characters, hence the dividing line between the subdivisions is purely arbitrary, and the personal equation enters largely into the matter, especially as the formations pass conformably into one another.

Description of Formations

Aldridge Formation.—The Aldridge formation is the oldest known sedimentary member of the Purcell series in the Purcell range. It consists of argillaceous quartzites and purer quartzites with a subsidiary amount of argillite. The beds vary in thickness from a few inches in the argillitic members, to 8 feet in the purer quartzites, but the average thickness of the strata is 6 inches. The argillaceous quartzites are grey to almost black in colour on fresh fracture. They weather to a rusty brown, and since the argillaceous quartzites are in greater abundance, they give the characteristic reddish-brown colour to the formation as a whole. The thick-bedded purer quartzites weather to a light grey colour. Shallow water features, except some conglomerates on Goat river, were not noticed in the Aldridge formation. In places, cubes of pyrite were abundant. A fact, worthy of emphasis, is that in this region the Aldridge formation is characterized by the presence of a relatively large number of thick gabbro sills called the Purcell sills. The succeeding younger formations contain only a few gabbro sills, and these are relatively thin and unimportant. The Aldridge formation contains the greatest number of economic ore-deposits, and in it are situated the St. Eugene, Society Girl, Aurora, North Star, and Sullivan ore-deposits[1]. Also, the majority of the copper-bearing veins occur in the gabbro sills which are intruded into the Aldridge formation.

Creston Formation.—The Creston formation rests conformably upon the Aldridge formation. A transition zone 500 feet in thickness separates the Aldridge and the Creston formations. The latter consists of a well-bedded series of grey argillaceous, purer quartzites, and sandstones with thin intercalations of argillite. The beds, averaging one foot in thickness, are often cemented together so that they form steep cliffs. In the western part of the range, in the vicinity of Goat river, the quartzites are coarser in texture, and resemble coarse sandstones in appearance, while in the eastern part they are finer-grained and more argillaceous. In general, the quartzites are grey on fresh fracture and weather to a grey colour, which is in distinct contrast to the weathering colour of the Aldridge formation. When the grey quartzites are impregnated with cubes of pyrite, they weather reddish-brown.

Ripple marks were noted at several horizons throughout the Creston formation. Intruded into the formation are a few diorite sills reaching a thickness of 100 feet.

Kitchener Formation.—Lying conformably upon the Creston formation and passing into it by gradual transition is the Kitchener formation, which is com-

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[1] S. J. Schofield, Geol. Surv., Can., Summary Report, 1911, p. 160.
S. J. Schofield, Ec. Geol., vol. VII, 1912, p. 351.

posed of calcareous argillites, calcareous quartzites, argillaceous quartzites and limestones, in beds whose average thickness is 6 inches. The weathering colour is reddish-brown.

Siyeh Formation.—Lying conformably on the Kitchener formation and passing into it by gradual transition occurs the Siyeh formation, which consists of purple and grey siliceous argillites in beds from 1 inch to 2 inches in thickness. Some dolomites and limestones are present in the upper part of the formation. The argillites are characterized by the presence of abundant mud-cracks and ripple marks.

Purcell Lava.—The Siyeh epoch was brought to a close by the outpouring of basalt called the Purcell lava. This lava consists almost entirely of amygdaloidal basalt with small amounts of rhyolite and breccia and is the extrusive phase of Purcell sills.

Purcell Sills.—The Purcell sills are not only of scientific interest but, economically, since they afford small deposits of copper ores. The sills occur as sheets of igneous material from 6 to 2,000 feet in thickness, intruded between the bedding planes of the quartzites, and occasionally as very small pipes about 400 feet in diameter. Most of these sills are composed of gabbro, but a few are composite and show great variations within the same magmatic chamber. The same composite sill, although believed to be simple in character, is heterogeneous in composition, that is, processes of differentiation have evidently affected the magma of these sills before solidification, with the result that the material of some of the sills is stratified according to density. In this case, a granitic layer appears at or near the upper contact of the sills, passing downwards into gabbro. The thickness of the granitic layer bears no relation to the thickness of the sill. The sills have probably been affected by all the movements which the enclosing sediments have undergone, and hence occur in all attitudes, from horizontal to vertical. The sills have evidently reached their present stratigraphic position through fissures, although very few dykes have been found within the region examined. The age of these intrusives is probably Pre-Cambrian.

Gateway Formation.—The lower part of the formation consists of alternating bands of massive concretionary siliceous dolomite and limestone weathering buff, and massive light grey quartzites. These are succeeded by thin-bedded sandy argillites and greenish grey siliceous argillites. The sandy argillites weather a light buff and are characterized by the presence of abundant casts of salt crystals.

Phillips Formation.—According to Daly the Gateway passes gradually into the overlying Phillips formation which consists of dark purplish and red metargillites and sandstones with thin laminae of greenish siliceous argillite intercalated at several horizons.

Roosville Formation.—The Phillips is overlain conformably by the Roosville which consists almost entirely of massive laminated green siliceous metargillites weathering greenish grey.

THE DEVONIAN LIMESTONE

In the Rocky Mountain system, the Devonian limestone apparently rests conformably upon the underlying Pre-Cambrian series, while in the Purcell range to the west, an apparent unconformity exists between the Devonian limestone and the Gateway formation. The staple rock of the Devonian is a massive dark grey limestone weathering a whitish-grey colour. The following fossils found in the limestone were identified by Dr. Kindle:—

Atrypa reticularis.
Spirifer pionionensis.
Orthothetes chemungensis var. *arctostriatus.*

WARDNER FORMATION

The dominant rock of the Wardner formation, which lies conformably upon the Devonian, is a whitish-grey crystalline limestone occurring in beds from a fraction of a foot to 4 feet in thickness.

The following fossils contained in the limestone, were identified by Dr. P. E. Raymond:—

Camarophoria explanata (McChesney)
Camarotocchia cf. *C. metallica* (White.)
Composita madisonensis (Girty).
Cleiothyrdina crassicardinalis (White).
Spirifer cf. *S. ccntronatus* (Winchell).
Productclla cooperensis (Swallow).

The above fossils point to a Mississippian age, Lower Carboniferous, for the Wardner limestone.

KOOTENAY GRANITE.

The Kootenay granite cuts all the members of the Purcell series in East Kootenay and occurs as small stock-like masses. The peculiar alignment of these bodies of granite along the lines of major faulting of the region cannot be accidental. It shows that the intrusion of the granite magma accompanied or followed the principal orogenic movements which affected the Purcell range. Cutting the granite itself as well as the sediments in the neighbourhood of the granite, occur aplite, lamprophyre, and pegmatite dykes which are records of the last known igneous activity in the Purcell range.

PLEISTOCENE DEPOSITS.

Lying unconformably on the old eroded surface of all the bed-rock formations, occurs a partly-consolidated stratified series of clays and sands, into which the streams have incised their courses, leaving well-developed terraces at various elevations above their flood-plains. In the neighbourhood of the St. Eugene Mission two seams of lignite are found in the stratified clays of the Pleistocene and probably represent an interglacial formation.

Regional Structure.

The Rocky Mountain geosyncline, which includes the greater part of the Selkirk, Purcell, and Rocky Mountain ranges, consists of Pre-Cambrian, Palæozoic, and Mesozoic sediments. Its western border passes through Coeur d'Alene, Kootenay, and Shuswap lakes, along whose shores is exposed the old crystalline complex, from which part of the above sediments was derived.

In passing westwards from the almost horizontal Tertiary and Cretaceous strata which make up the elevated plateau of the prairie provinces, we meet first the folded region of the foot-hills which contains the most easterly evidences of orogenic movements in the Rocky Mountain geosyncline. These folds trend in a northwest-southeast direction and represent the most easterly effects of the strong compressive forces which built the Rocky mountains proper lying to the west of the foot-hill area. The eastern part of the Rocky mountains, which are made up of Palæozoic and Mesozoic strata, consists of a series of overthurst fault blocks, striking in a northeast-southwest direction and dipping to the northwest.

In the western part of the Rocky mountains, anticlines and synclines of Cambrian and Palæozoic strata make up the dominant structure, thus placing the zone of maximum movement in the central or eastern part of the range.

In passing from the Rocky mountains on the east to the Purcell range on the west, the wide Kootenay-Columbia valley is crossed. This topographic feature, which is of first importance in the structure of the region, is called the Rocky Mountain trench. The rocks which form the greater part of the Purcell range are Pre-Cambrian in age and their structure is entirely different in character from that of the Rockies. In southeast Kootenay, the Purcell sediments were first folded into a series of northerly plunging anticlines and synclines. Later these folds were truncated by normal faults which strike in a northeast-southwest direction and hence trend in a direction at right angles to those of the Rocky mountains. Also it is probable that the fault system of the Rockies truncates that of the Purcells, for, in the Rocky Mountain trench, a block of Mississippian limestone is down-faulted in contact with the Pre-Cambrian quartzites, and this block trends in a northwest-southeast direction. From the above facts it is probable that the Purcell range was built prior to the Rockies and that the two ranges are structurally separated by the Rocky Mountains trench.

Age of Faulting.—From the presence of the Mississippian limestone in such thickness as exhibited in Kootenay River valley, it is probable that Carboniferous rocks at one time extended over part of the Purcell range and have since been removed by erosion. Thus the faulting is post-Carboniferous in age. In addition, the fact, that the fault system of the Rockies apparently truncates that of the Purcell, proves that the Purcell faulting is of pre-Laramie age. G. M. Dawson[1] first recognized the possibility of a pre-Laramie mountain range in the Purcell range, as shown by the following extract: "the Triassic period was closed by one of those epochs of folding and dislocation of strata which are found to be recurrent in geological time, and which are generally attributed to contraction of the earth's crust. It is highly probable that some corrugation along the line of the Rocky mountains occurred at the same period, as, in the earlier Cretaceous strata next succeeding, without further evidence of disturbance, conglomerates are found composed of fragments of many varieties of older rocks, which could scarcely otherwise have been rendered subject to denudation. Though much remains to be discovered respecting this post-Triassic epoch of disturbance, it was evidently an important one and its results are wide-spread in the Cordilleran region. It is quite possible that it was accompanied by or resulted in producing a general elevation of this entire region above sea-level, as no rocks certainly referable to the Jurassic or next succeeding period have yet been distinctly recognized either in British Columbia or in its neighbouring region." Since the time that the above was written, marine Jurassic rocks have been found in the Rocky mountains to the east. These rocks consist of black shales which conformably underlie the Kootenay formation of the Lower Cretaceous consisting of conglomerates and shales. Hence the date of the orogenic movements, which built the range, from which these conglomerates were derived, occurred probably at the close of the Jurassic. This post-Jurassic mountain range was built along the old 'Archæan' land, which supplied the material now forming the Pre-Cambrian sediments of the Purcell range, which in its turn, supplied part of the material for the Cretaceous strata now folded and faulted along with the Palæozoic sediments of the Rocky Mountain range. The Rocky Mountain range came into existence at the close of the Upper Cretaceous or in the early Tertiary and, in its turn, supplied the sediments of the flat-lying Tertiary of the plains.

[1] Dawson, G. M., Trans. Roy. Soc., Can., vol. VII, sec. 4, p. 7.

Local Structure.

The structure of the southern part of the Purcell range is characterized chiefly by broad open folds. Normal faulting plays a minor role, in fact, only two major faults were noted in the region between the Crowsnest branch of the Canadian Pacific railway and the International Boundary line.

The structure of the Moyie mountains, the most westerly part of the Purcell range in the region examined, consists of a monocline of the Aldridge formation dipping to the east. The eastern boundary of the monocline is formed by the Moyie fault which locally occupies the Moyie River valley in the vicinity of the International Boundary line. To the east of this fault lie the Yahk mountains which form the core of the Purcell range in this region. The dominant structure of the Yahk mountains is a broad anticline whose axial portion is composed of the argillaceous quartzites of the Aldridge formation, while its radial portion on the west is formed of the Creston formation. The eastern limb has been modified by a minor syncline which exposes along its axis the argillites of the Siyeh formation. Thus the Yahk anticline presents an irregular ground plan. To the east of the Yahk mountains, whose eastern border is formed by the main Yahk river, lies the McGillivray mountains, whose dominant structure is a shallow syncline with both eastern and western limbs passing into anticlines. The axis of this mass strikes in a northerly direction. The western limb of the anticline is eroded deeply enough to expose the highest members of the Aldridge formation, while the eastern limb is composed of the argillites of the Siyeh formation. This anticline is broken on its crest by a normal strike fault which to the north brings the western limb of the Gateway syncline in contact with the eastern limb of the anticline in such a way that the Siyeh argillites appear to rest conformably upon the Gateway formation. This fault in the region south of Cranbrook repeats the outcroppings of the Purcell lava which is exposed near the summits of Moyie and Baker mountains.

The eastern slope of the McGillivray mountains north of Plunbob creek and south of Mayook station on the Canadian Pacific railway which overlooks the Kootenay valley, is covered with Devono-Carboniferous limestones. These limestones rest upon the Gateway formation with a probable unconformable contact. The small patch of Devonian limestone noted on Gold creek rests upon the Purcell lava and the Gateway formation, and hence strengthens the evidence for an unconformity between the Devonian and the underlying Purcell series in the Purcell range. The alternative explanation of the relations described above, is that a block of Devonian limestone has been thrust over the Purcell series from the east, and the block has been greatly eroded with the result that two patches of Devonian limestone have been left in the Gold Creek valley.

CLAY INVESTIGATIONS IN WESTERN CANADA

(Heinrich Ries)

As a result of the somewhat extensive examination which was made of the clay and shale deposits of the western provinces during the seasons of 1910 and 1911, we have obtained a pretty clear idea of the clay-bearing formations and the character of the materials to be found in them. During the summer of 1912, several months were spent in examining those areas which lack of time had prevented me from seeing during the two previous years. I was assisted in this work by E. D. Elston.

In the present summary the subject can be best taken up by areas instead of formations, and reference is made only to the important regions. Those of minor importance will be discussed in the final report.

Edmonton to Yellow Head Pass

Considerable new territory is being opened up by the main line of the Grand Trunk Pacific from Edmonton to Prince Rupert, and this belt was investigated as far as Grand Forks, which is about 40 miles west of the British Columbia-Alberta boundary.

In a previous report[1] reference was made to the shale deposits exposed in the Pembina gorge near Entwistle, Alberta. It is probable that these shale deposits may extend westward for some distance but the heavily wooded character of the country, and low relief, makes any search for them difficult, except by means of boring. The first good section along the main line west of Entwistle, is in the banks of Wolf creek, where beds of greyish shale, and shaly sandstone are exposed.

The shale is very plastic, and dries without cracking, but has a rather high air skrinkage, so that it would be well to add some of the shaly sandstone to it. The burning tests on this are not yet completed. It is probable that the same shales can be found in the banks of McLeod river. In the Jasper Park coal field, the shales associated with the coal seams are usually quite gritty, but some are sufficiently plastic for brick manufacture, There are also some pockets of Glacial clay in this region that could be utilized.

West of Pocahontas the rocks are hard, massive, and somewhat metamorphosed by folding, so that the argillaceous beds are too slaty to be used for clay products.

Southern Alberta

The Belly River shales are known to underlie a wide expanse of territory from Medicine Hat to Lethbridge, and parts of this have been reported on in the earlier work. Among the new localities visited last summer were those near Bow Island and north and south of Lethbridge.

North of Bow Island station, and close to Belly river, shale exposures of the Belly River series are found in the hills and slopes overlooking the river, but

[1] Geol. Surv., Can., Memoir 24E.

the outcrops are more or less covered with wash and grassy growth. The section is more or less characteristic of the Belly River formation, and shows alternating layers of plastic clay shales and some sands, with occasional seams of coal. The beds are all red burning.

Northeast of Lethbridge, in the curve of Belly river, there are some excellent exposures in the cliffs, the upper half of which, in a section of about 100 feet, is sufficiently plastic to work up into bricks.

South of Lethbridge, at the junction of the Belly and St. Mary rivers, is a fairly thick section of shaly beds, with occasional lignite seams. The entire section is probably 100 feet thick, but the shale is not all segregated in the same portion of the section. Indeed the better part of the shale is near the bottom of the bank. However, there is red-burning shale, and surface clay near the top which could be worked for bricks, and which appears to be sufficiently plastic to flow through a die. This could be obtained without much stripping.

Prospecting west of Lethbridge, towards McLeod, would probably result in finding shales of the same type as are worked at Calgary, and Sandstone. At any rate, there is to be obtained in the region around Lethbridge much better brick material than is now being utilized there.

From Lethbridge towards the International Boundary no shale exposures are found along the railway, but there are occasional deposits of Glacial clay.

Gleichen

An interesting section is found about one-half mile west of Gleichen, and only a few hundred feet north of the Canadian Pacific railway track. This is pretty close to the boundary of the Miocene and Edmonton as shown on the geological map[1], but it probably falls in the Edmonton.

The section here shows not less than 25 to 30 feet of shale which is quite plastic. As the shale in the upper part of the bank cracks in drying and has a high air shrinkage, it should be mixed with the material in the lower part. The deposit is very favourably located for working and shipment. Fire tests have not yet been made.

Crowsnest Pass District

Comparatively little intelligent prospecting for clay has been done in this region. It is highly probable, however, that with the development of the coal basins in this region means of access to the shale deposits will be found.

Some excellent plastic clays are found near Jackson creek, which is a branch of the South Fork. They occur in the Benton shales. The same formation at other points carries black shales of almost slaty character, and since the two are in some cases at least known to be at the same horizon, it suggests the possibility of a transition from one to the other along the same bed.

In considering the workability of the Benton shales, such factors as transportation and size and character of the deposits enter into the question. If underground methods are adopted the clay should be high grade, the beds should not be steeply inclined, and the roof should be solid so as to reduce timbering to a minimum,

The black Benton shales, so far as our experiments show, are lean and granular, but mix up well with the better clays from the same formation.

The black shales are well exposed on G. H. Bradley's property, west of Coleman, and also about 2 miles southeast of Blairmore. In neither case is the material

[1]Can. Geol. Surv., No. 1010, 1909

sufficiently plastic to be used alone, and it should be mixed with a more plastic clay. The laboratory tests are not yet sufficiently far advanced to determine its refractoriness.

Along Crowsnest lake, west of Coleman, the Allison formation carries beds of hard greenish shales, interbedded with sandstones. The shales occur irregularly and form lenses of variable size in the sandstone. The beds in most cases dip rather steeply to the southwest.

These shales have recently attracted attention because of their possible use for sewerpipe. The thickness and extent of the deposits has not been determined.

About one-half mile south of Crowsnest station, in township 8, section 11, range 6, west of 5th meridian, the section shows:—

Black shale	25 feet.
Shaly sandstone	15 "
Black carbonaceous shale	40–50 "
Black shales	100 "

The series dips rather steeply, and the lower member could be worked without removing the overlying one. The material is sufficiently plastic to mould and is red-burning.

Columbia Valley Silts

Reference was made in last year's report to silty clays found in the Columbia River valley at Golden. Farther up the valley, and begining at a point about 20 miles north of Spillimacheen, there appear banks of a yellowish white, compact silt, which underlie a terrace formation that can be traced almost continuously to Canal Flats, at the source of the Columbia river.

These deposits, which are of remarkable extent, are usually made up of a fine calcareous silt, but in places there are pockets and beds of more clayey material, and occasional streaks of pebbles. Around Canal Flats the material forms high bluffs, which rise to probably 150 to 200 feet above the valley bottom. Similar material is found in the bluffs around Fort Steele, as well as between Fort Steele and Wassa.

The utilization of this vast silt deposit forms an interesting problem. It has been used for making a rather porous brick near Athelmere, and yet it is not a satisfactory material to use for brick manufacture, for although some of the beds are fairly plastic, the majority are not so. Experiments are now under way to determine what can be done with this extensive deposit.

Columbia River Valley North of Revelstoke

The rocks in this valley between Revelstoke and Downing creek, are folded and metamorphosed sediments, and where exposed along the river, gave no promise of yielding material suitable for the needs of the clay-working industry.

From Revelstoke to Ford river, the surface deposits are gravelly, but north of there at several points there are deposits of grey stratified plastic clay, which could be utilized for brick and possibly drain tile. Adjacent to some there is sufficient flat or gently sloping ground to build a brick plant for working up the material.

Though these deposits may only be adapted to common brick manufacture, their possible importance should not be overlooked, since Revelstoke has at present no nearby source of supply of good common brick. A branch of the Canadian Northern railway is surveyed down this valley, and the product could also be distributed west and south from Revelstoke.

Princeton District

There are some Pleistocene surface clays to be found in this district and also some shales, but some of them are rather gritty. One very plastic red-burning shale is found at Coalmont in the mines of the Columbia Coal and Coke Company.

Fraser Valley, New Westminster to Silverdale

The deposits of stratified surface clays of Pleistocene age have been referred to in an earlier report, especially those worked on both sides of the Fraser river near New Westminster, and at Port Haney. Since last year some new plants have been started on the north side of the stream. But on the south side, opposite Silverdale, there are high banks of red-burning stratified clays, along the new line of the Canadian Northern railway, which could be similarly utilized to supply the Vancouver market. Like those already worked in this region, they could be manufactured into brick and drain tile.

Vancouver Island

The shales of the Northumberland formation form a tempting material to brick manufacturers. Samples of some of these were collected during the field season of 1911, and after careful tests in the laboratory it was suggested that their utilization should be undertaken with great caution, for the reason that they were hard, did not slake easily, and were very gritty. As a result of this they have to be ground very fine, in order to develop any satisfactory plasticity in them. Moreover, they must be carefully studied in order to get them to work in a stiff mud machine. They must also be slowly and carefully burned, firstly because some of them are carbonaceous, and secondly because they are easily overburned, and yield a product of undesirable colour.

In some cases that part of the shale deposit nearest the surface has been altered somewhat by prolonged weathering, and this portion works much better, but these early results are likely to lead the manufacturer to think that the whole deposit may work this way, and so any preliminary tests should deal with the unweathered shale as well as the surface weathered rock.

In writing thus, there is no intention to claim that these shales are absolutely worthless, but simply to show that they are a hard proposition to handle, and in any case their use will probably be attended with long and costly experimenting, which will be the greater, the less experience the manipulator has had with brick machinery and shales.

In any event, the extra care needed in making bricks from these shales is very likely to make their cost of manufacture more expensive, than if other more tractable material were used.

There are clay deposits on the mainland which would work up better than these shales, and the recent railway excavations made in the vicinity of Vancouver show that Tertiary shale-bearing formations lie at no great distance below the surface. These last named shales are softer and more plastic than the Nanaimo ones, but the deposits are not as well exposed, and must be searched for.

Prince Rupert

The fact that this town is the terminal of the Grand Trunk Pacific railway, and is steadily growing, will no doubt create a demand for burned clay wares especially bricks.

The mainland does not appear to carry any shale deposits of value, but there are abundant deposits of surface clays, of glacial origin. Small deposits occur near Prince Rupert, and another is at mile 85 on the Grand Trunk Pacific railway east of Prince Rupert. Additional deposits are found on Porcher and Graham islands.

DEVELOPMENTS IN THE CLAY INDUSTRY

During the past year there have been a number of important developments in the clayworking industry of the western provinces.

The Alberta Clay Products Company at Medicine Hat has increased the capacity of its plant by the construction of a number of additional circular down draft kilns. The product is largely fireproofing and is in good demand. The company have made some extensive openings in the hill near Coleridge where they obtains their clay. A second dry-press brick works is in operation near Redcliff, and wins its clay from underground workings. The Purmal and Pruitt brick plant at Medicine Hat has been rebuilt after the fire, and is again in operation.

A stoneware pottery was under construction at Medicine Hat in the summer of 1911, There are no stoneware clays at that locality, and the company may bring their raw material from the Dirt hills.

Around Calgary the plants using the Tertiary shales are still in operation. A new one, the Tregillus Clay Products Company,is being built just west of Calgary, and at Sandstone the Sandstone Brick and Sewerpipe Company has also begun operations. Both these new plants will make brick at first, but state that later they will develop the manufacture of other classes of clay products as well.

No new plants have been started at Edmonton, but some of those already in operation have expanded their works somewhat.

On the Pacific coast two new plants have been started along the Fraser river near Port Haney. The plant of the Kilgard Fire Brick Company on the south side of Sumas mountain is also under construction.

On Vancouver and the adjoining islands there has been considerable activity in utilizing the Northumberland shales. The plants established are three in number. The first, that of the Mountain Brick and Tile Company, has begun the making of stiff-mud brick at East Wellington near Nanaimo. The second is the Coast Shale Brick Company making shale brick by the stiff-mud process on Pender island. A third is the Dominion Brick and Tile Company, making dry-pressed brick from shales on Gabriola island. All three of these were still in experimental stage in September, 1912. A fourth plant is said to be planned, and is to be located on Denman island.

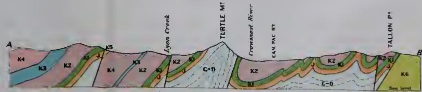
BLAIRMORE MAP-AREA, ALBERTA

The geological and topographical mapping of this area was completed during the season of 1912. Pending the publication of the completed topographical and geological maps on a scale of about 1 mile to 1 inch, the accompanying map, on a smaller scale, is issued. The geological mapping was performed by W. W. Leach during the seasons of 1911 and 1912.

Canada
Department of Mines

Hon. L. Coderre, Minister A P Low, Deputy Minister

GEOLOGICAL SURVEY
R W Brock, Director



Structural Section along line AB
Scale: horizontal and vertical, 10,560 feet to 1 inch

GEOLOGY

PRELIMINARY MAP

G.O. Seneal, Geographer and Chief Draughtsman.

LEGEND

MESOZOIC

UPPER CRETACEOUS

K6 Undivided (post Benton, probably including Allison, light coloured sandstone)

K5 Allison (Belly River?) formation (light coloured sandstone)

K4 Benton formation dark shale

K3 Crowsnest Volcanics (analcite trachyte tuff and breccia)

LOWER CRETACEOUS

K2 Blairmore (Dakota?) formation (chiefly dark sandstone and sandy shale)

K1 Kootenay formation (coal, shale, indurated sandstone)

JURASSIC

J Fernie formation dark shale

PALAEOZOIC

CARBONIFEROUS AND DEVONIAN

C-D Turtle Mountain group light coloured, cherty limestone

Anticlinal axis

Synclinal axis

Fault

LEGEND

Railways

Roads

Trails

LIST OF MINES

1. McGillivray Creek Coal and Coke Co Ltd
2. International Coal and Coke Co Ltd
3. West Canadian Collieries Ltd
4. Canadian Coal Consolidated Ltd
5. Hillcrest Collieries Ltd
6. Maple Leaf Coal Co
7. Leitch Collieries Ltd
8. Davenport Coal Co Ltd

MAP 107A
(Issued 1913)

BLAIRMORE, ALBERTA.

Scale of Miles

Geology by W W Leach, 1912
Base Map by Topographical Division

To accompany Summary Report, 1912

Canada
Department of Mines
HON L. CODERRE MINISTER A P LOW, DEPUTY MINISTER

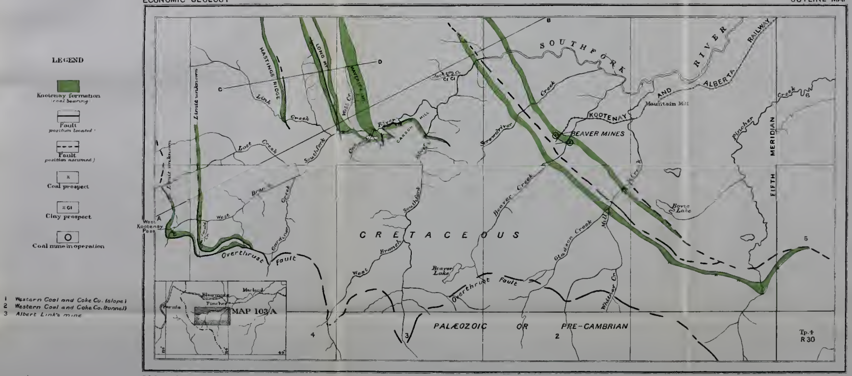
GEOLOGICAL SURVEY
R W BROCK DIRECTOR

Diagrammatic structural section along line CD
Scale, horizontal and vertical, 15,840 feet to 1 inch

Diagrammatic structural section along line AB
Scale, horizontal and vertical, 15,840 feet to 1 inch

ECONOMIC GEOLOGY

OUTLINE MAP



C.O. Senecal, Geographer and Chief Draughtsman

MAP 103A
(Issued 1913)

SOUTHFORK COAL AREA, OLD MAN RIVER, ALBERTA.

Scale of Miles

To accompany Summary Report by J.D. Mackenzie, 1912.

SOUTH FORK COAL AREA, OLDMAN RIVER, ALBERTA

(John D. MacKenzie)

Introduction.

The greater part of the field season of 1912 was spent in making a geological examination of the southward extension of the Blairmore-Frank coal fields in southwest Alberta. The northern part of the area examined is drained by the South Fork of Oldman river, and is locally known as 'the South Fork district.' Part of the area is included in the Rocky Mountains Forest Reserve.

The area covered comprises most of township 6, ranges 2, 3, and 4; township 5, ranges 1, 2, 3, and 4, west of the 5th principal meridian (114°), and a part of township 5, range 30, west of the 4th principal meridian. In all about 250 square miles were mapped geologically, of which about 90 square miles in the valley of the South Fork river were examined in considerable detail, a reconnaissance having been made over the remainder.

The writer is indebted to Mr. W. W. Leach of the Survey for assistance in becoming acquainted with the sections and structure of the rocks near Blairmore, and for many other courtesies. Thanks are also due to Mr. J. A. MacDonald, of the Premier Coal and Coke Co., Ltd.; Mr. M. J. Rhinas, of the Coal Securities, Ltd.; Mr. Maxwell, of the Western Coal and Coke Co., and to others for assistance and information while in the field.

The field party consisted of four persons, including Mr. C. L. Cumming, to whom thanks are due for his services as assistant.

Previous Work.

G. M. Dawson, during his exploration of the Rocky mountains, in the eighties, traversed the valley of the South Fork river, and crossed the Rockies over the North Kootenay pass, out of which the west branch of the South Fork river flows. He gives a short narrative description of this portion of the district[1].

W. W. Leach, in 1902, made a geological sketch map of the Blairmore-Frank coal fields, immediately to the north of this area. The southern boundary of his map is virtually the northern limit of the present work.[2] He also measured some sections in the same district in 1911[3].

Summary and Conclusions.

The district is wholly underlain by sedimentary rocks ranging in age from the Devono-Carboniferous measures of South Turtle mountain, to the middle or Upper Cretaceous, an apparently completely conformable section being obtained throughout the series.

Sandstones, shales, and conglomerates make up the bulk of the sediments,

[1] G. M. Dawson, Geol. and Nat. Hist. Surv. of Can., part B., Annual Report, 1885, pp. 55–61. See also *ibid*, Annual Report, 1882–84, p. 5, etc.

[2] W. W. Leach, Geol. Surv., Can., Annual Report, vol. xv, 1902, pp. 169, etc.

[3] W. W. Leach, Summary Report, Geol. Surv., Can., 1911, pp. 192–200.

with some limestone in South Turtle mountain, and the Crowsnest volcanics, and important tuff intercalation at the top of the Dakota. The rocks are strongly folded, and severely faulted in nearly all cases by strike faults, giving a number of virtually parallel bands of repeated coal measures and other rocks. The faults have not, in most cases, it is believed, disturbed the coal in such a manner as to render mining unprofitable; instead of this, huge blocks of the earth's crust have been tilted and lifted sufficiently to make the coal easily accessible.

Glacial deposits other than erratic boulders are rare, or absent. The valleys of the larger streams are bordered by stream terraces of coarse gravel and sand.

Economic resources are confined to non-metallic products, chiefly coal, clays and shale, limestone, sand and gravel, and possibly paint rock.

General Character of the District.

TOPOGRAPHY

The district examined has for its western and southwestern boundary the abrupt escarpment of the Rockies, and so may be considered as part of the foot-hills of those mountains. The Rockies in this part of the Cordillera do not reach the altitudes that obtain farther north along the main line of the Canadian Pacific railway, there being probably no peaks over 10,000 feet high, yet they are very rugged, and distinctly of the Alpine type of topography.

The foot-hills themselves, with which this report deals, are characterized by a parallel series of ridges, often maintaining uniform heights for several miles; attaining an altitude of 6,000 feet or more in the western part of the area, where they are often of knife-like sharpness, gradually decreasing in elevation and steepness of slope as the plains are approached. These ridges are caused by parallel, alternating bands of hard and soft rocks, repeated by faulting and folding. The relief of the district is about 1,800 to 2,000 feet. The width of the foot-hill belt on the west branch of the South Fork river is about 20 miles; this distance (from the escarpment of the front range to the plains) decreases as one goes south until in the vicinity of the head-waters of Pincher creek it is not more than 10 miles, in a direction somewhat north of east.

Cutting directly across these ridges are the valleys of Link and Canyon creeks, and the west and south branches of the South Fork river, continued in the South Fork river itself, in the northern part of the district; and Screwdriver, Beaver, Gladson, Whitney, and Mill creeks as one goes southward, all tributaries of the South Fork river, also Pincher creek, running into the Oldman river. North of the easterly trending valley of the west branch of the South Fork river, the ridges run a few degrees west of north as far as the Crowsnest river, a distance of from 10 to 15 miles. South of the valley the direction bends more to the east, and the ridges run about S. 45° E. until the valley of Pincher creek is reached, where the last of the hills, which have been gradually disappearing, turns northeastward and is merged into the plains within 3 or 4 miles.

All of the streams above mentioned intersect the strike of the rocks almost at right angles; they form the main drainage system of the district, and run in a general northeasterly direction in relatively broad valleys, while the narrower and steeper longitudinal valleys between the ridges, parallel to the strike of the rocks, are occupied by subordinate streams.

The valleys of Link and Canyon creeks, and of both branches of the South Fork river follow lines of structural disturbance more pronounced than obtains in most parts of this region, and there is some evidence that other transverse valleys of the district are of analagous location. The significance of this has

not been investigated as yet; but it may be noted that Dawson[1] mentions a similar relation in regard to the Crowsnest (middle fork Oldman) river, to the north of this area.

The larger streams are bordered by well-marked terraces, as many as five, one above the other, being noted in some cases.

Glacial action has not modified the topography of the foot-hills here to any marked extent. With the exception of numerous large boulders of the Crowsnest volcanics and occasionally of other local rocks which are found at all altitudes, there are scarcely any superficial deposits that could be attributed to the effect of ice occupation of the district. In one locality on Screwdriver creek some kame-like mounds were seen, but time did not permit of detailed study. Many of the ridges are sharp and ragged on top; and even on these prominent bare ledges there are no signs of glacial action, and the minor longitudinal valleys are clearly of a V-shaped cross-section. It is probable that valley glaciers occupied the present larger valleys, but these are now so obscured by river drift and terraces that possible glacial scorings on the rocks are hidden.

CLIMATE AND VEGETATION

The climate is bracing and pleasant, although the season of 1912 was exceptional in that July was very cold and wet. Very hot days are not common, and field work can be carried on under favourable conditions of temperature. Snow first appears on the peaks of the Rockies late in August, and occasional snows occur in the foot-hills area in September.

The western part of the foot-hills is heavily forested, often right up to the escarpment of the mountains, with excellent stands of large spruce and some fir, and much of this area has been untouched by fire.

Eastward, the hills are for the most part bare, in some localities covered with burnt small timber, but generally grassed to the summits, and dotted with clumps of poplar and balm-of-gilead, nearly always of small size. Even these trees become less frequent as the plains are approached. The extreme profusion and beauty of the wild flowers of these grassy hills are worthy of mention.

MEANS OF ACCESS

A wagon road extends from Lundbreck and Burmis, on the Crowsnest branch of the Canadian Pacific railway, up the valley of the South Fork river to within 6 miles of the summit of the North Kootenay pass over the Rocky mountains, and is continued by a pack trail over the pass into the Flathead valley. From Beaver Mines, connected with the Canadian Pacific railway by rail, a wagon road crosses the hills into the valley of the south branch of the South Fork river at Kellys Crossing, and thence follows the western of the two large streams that meet here, until within 3 miles of the Continental Divide, and well inside the high mountains. Besides these two main roads, numerous trails, passable for pack animals, intersect the district.

General Geology.

The rocks of the area are, on the whole, well exposed, and the structure, though complex, can be elucidated in a general way with considerable certainty, but the minor structures, a knowledge of which is so vital to mining operations, are often not apparent from surface exposures.

An apparently conformable section has been obtained in this area, from the so-called Devono-Carboniferous to the Upper Cretaceous.

[1] G. M. Dawson, Geol. and Nat. Hist. Surv. of Canada, part B, Annual Report, 1885, p. 67.

Table of Formations

Pleistocene and Recent	Superficial deposits.
	Unconformity.
Upper Cretaceous	Allison formation (Belly River).
	Benton formation.
	Crowsnest volcanics.
	Dakota (?) formation.
Lower Cretaceous	Kootenay formation.
Jurassic	Fernie formation.
Devono-Carboniferous	Limestone of Turtle mountain.
	Fault Contact.
	Red beds of North Kootenay pass.

DESCRIPTION OF FORMATIONS

Red Beds of the North Kootenay Pass.—These rocks, outcropping prominently in the eastern escarpment of the Rockies, lie outside the province of this report, but their occurrence deserves mention. Dawson called these rocks Triassic[1], but the evidence seen this summer, while admittedly incomplete, goes to show that they are of much greater age.

The red beds are thrust over the Cretaceous rocks to the eastward by an overthrust fault of great magnitude, and consist of about 2,000 feet of brilliant red, siliceous laminated shales, with some pale green quartzose shales, and two or three hundred feet of eruptive and intrusive volcanic rocks near the base. The volcanics are underlain by platy, dark blue to greyish, buff weathering limestone. Possibly these beds are to be correlated with the Kintla argillite and Siyeh limestone of the Lewis range in northern Montana[2]. They do not occur in the foot-hills area proper.

Devono-Carboniferous Limestone Series.—These beds, a small area of which is exposed along the axis of the Turtle Mountain anticline in the northern part of the district, have not been examined in this area. They consist of pure and cherty limestones, and have long been called Devono-Carboniferous in age. Mr. Leach has found fossils in these beds (personal communication), immediately under the Fernie shales, in the Blairmore district, north of the one under consideration.

Fernie Formation.—The Fernie shales, as these beds are known throughout the Rocky Mountain province, are dark grey to black, fine-grained clay shales, interbedded with which are fine, grey, siliceous and argillaceous sandstone bands. These measures lie apparently conformably on the limestone of Turtle mountain, supposedly Devono-Carboniferous in age. They are often highly contorted, being of a yielding nature, and so the thickness cannot always be determined.

Fossil shells, and at one locality, vertebrate bones, have been found in the Fernie.

Kootenay Formation.—As it is conformable on the underlying Fernie, the Kootenay can only be separated from that formation arbitrarily in this district. Where the arenaceous beds or sandstones become of frequent occurrence the boundary of the formations has been placed, but there is no distinct break between the two.

The Kootenay beds are distinctively arenaceous, and universally of a grey colour; this distinguishes them from the green sandstones of the overlying Dakota. At the base the Kootenay is thin-bedded, and contains numerous shaly layers; as the top is approached, the beds become more massive, coarser, and much

[1] G. M. Dawson, Geol. and Nat. Hist. Surv. of Can., part B., Annual Report, 1885, p. 60.

[2] Bailey Willis, Lewis and Livingston ranges, Montana, Bull. Geol. Soc. of America, 1902, pp. 306–352. (See especially pp. 316 and 323–324).

minor cross-bedding is developed, and it is in these uppermost Kootenay beds that the coal seams are found. At the top of the coal measures is a remarkably persistent bed of a medium-grained siliceous conglomerate, composed of well rounded pebbles of black and white chert set in a hard siliceous matrix. The conglomerate is of varying thickness up to 20 feet and is of the greatest assistance in tracing the coal seams. A measured section of Canyon creek gave 1,285 feet from the lower Fernie (base not exposed) to the top of the conglomerate at the top of the Kootenay. About midway in this section, sandstone bands become noticeable in the Fernie shales, and the contact of the Fernie and the Kootenay is provisionally placed at this point.

Dakota (?) *Formation*.—The Dakota beds in this district are largely sandstones, with some irregular, lenticular bands of coarse conglomerate, and one persistent bed of limestone, near the middle of the formation. The sandstones are typically green; light green to brilliant deep green in colour, generally hard, and are fine to medium grained. Although very massive in some places, the sandstone bands are not persistent, and cannot be relied on as horizon markers. The conglomerate of the Dakota is occasionally mistaken for that over the coal measures, but may be distinguished by its greater coarseness, softness, and different weathering. The limestone in the Dakota occurs as a band from 4 to 20 feet thick, near the middle of the formation. Some fossil shells have been found in this band. Above the limestone, the Dakota is often very calcareous and characterized by seal-brown weathering green sandstones. Near the top of the formation occur several bands of bright red argillaceous shales. The Dakota is about 2,500 feet thick.

Crowsnest Volcanics.—This important intercalation of tuffs and agglomerates rests conformably and gradationally on the upper Dakota, and is likewise conformable under the Benton above. The beds consist of well stratified volcanic material of widely varying microscopic appearance, generally dark grey green to brownish beds, with all gradations of size, texture, and type of sediment. The tuffs usually outcrop on the tops of ridges, and, like the conglomerate at the top of the Kootenay, form an excellent index for determining the structure of the region. These beds thin out rapidly southward and eastward, and finally disappear. Their maximum thickness in the district is about 1,000 feet, exposed in a high ridge that runs northward from Link creek to west of Coleman, on the railway. Specimens from the northern extension of these rocks collected by W. W. Leach, in 1902, have been studied petrographically by C. W. Knight, who speaks of them as typically an analcite-trachyte tuff[1].

Benton Formation.—The rocks known as the Benton formation in this area consist almost wholly of dark grey to black fissile clay shales. Near the top of the lower third of the measures occurs a bed of very hard, fine- to medium-grained, quartzose sandstone, ordinarily from 10 to 20 feet thick, but in the vicinity of the North Kootenay pass this band has increased to 150 feet. Above this hard band, which often outcrops as a low ridge in the valleys caused by erosion of the soft shales, the measures are rather more arenaceous. The thickness of the Benton has not been well determined, for owing to its soft character, exposures are infrequent, but it is probably not less than 2,000 feet. Fossil shells occur sparingly.

Allison (*Belly River*) *Formation*.—These beds lie conformably on the Benton shales, and stratigraphically are the youngest of the bed-rock formations. Sandstones predominate, mostly white or light grey, sometimes pale green, massive, or with shaly structure, often beautifully laminated and crossbedded, and rather soft. Some considerable beds of dark grey shales occur, also several beds of light

[1] C. W. Knight, Canadian Rec. Sci., vol. 9, No. 5, 1905, pp. 265-278.

green plastic shales. The top of these beds was not observed, but about 2,000 feet are exposed on the west branch of the South Fork river. Fossils are rare, but a few shells have been found.

Superficial Deposits.—Superficial deposits are confined to river and stream drift; terraces, which are abundant and excellently developed; talus slopes and deposits of that nature, and erratic boulders. These latter are virtually the only evidence of glacial action in the district, and are usually from one of the heavier bands of the Crowsnest volcanics. Occasionally limestone boulders are found, but all can be accounted for originally within a rather restricted area, indicating that glacial transportation has not been very extensive here.

Structural Geology.

Structurally, this district belongs in the highly faulted and folded foot-hill region of the Canadian Cordillera adjacent to the eastern escarpment of the Rocky mountains. It is characterized by numerous parallel strike faults, accompanied by severe folding. Of these faults, the plane of the easternmost is vertical or highly inclined, and its throw is probably not less than 6,000 feet; the western fault, bringing the underlying Pre-Cambrian(?) measures up to the Kootenay, has a plane gently dipping westward, and the displacement of the beds along this plane is certainly also very great. The breaks occurring between these two boundary faults, while large, are not of the same magnitude, and are all vertical or highly inclined to the westward. The structure is evidenced areally by parallel strips of repeated measures, these strips coalescing with considerable complication as the folds and faults die out to the southward. This gradual dying out of faults is also a notable feature of the area. The throw of these overthrusts gradually decreases southward, until the break does not suffice to shift one formation past the overlying one, and the areal expression of the fault is then obscured as the dips in these disturbed measures are not always conclusive. The strike of the faults in the northern part of the district is N. 10° W. to N. 15° W.; in the southern part it gradually shifts round to N. 45° W. or N. 50° W. Finally, at the south-east extremity of the faulted Lower Cretaceous area, the strike turns to the north-east. It is thus seen, when a comparison of the strikes of the faults and of the rocks is made with the direction of the ridges and hills of the area, that the geological structure has had the greatest influence on the topography.

The dominant structural feature of this region is the Turtle Mountain anticline, and its attendant faulting and folding. Northward, along the axis of this fold are South Turtle, Turtle, and Bluff mountains, giving the anticline its name. It is a southward plunging fold, disappearing shortly after crossing the South Fork river, the axis striking nearly due north from here until it passes out of the area under consideration.

The western limb of this great fold is broken by a number of virtually parallel strike faults, giving three ridges of coal-bearing Kootenay rocks in township 6, range 4, west of the valley of Webb creek, which has its course sensibly along the anticlinal axis. Farther west, immediately under the rugged peaks of the Flathead range are two other bands of Kootenay rocks, brought up again by strike faulting, and extending from the middle of township 5, range 4, well up into township 6, ranges 4 and 5.

The eastern limb of the Turtle Mountain anticline is characterized more by folding than by faulting. East of the valley of Webb creek, on Maverick mountain, is a band of coal-bearing rocks; then the coal measures lie below the surface until again twice repeated by faulting, and exposed in two virtually parallel ridges running three-fourths to one mile apart, southeast from the northwest

corner of township 6, range 3, diagonally through townships 5 and 6, range 2, into township 5, range 1, west of the 5th where the eastern ridge is cut off by faulting. The western band is continued in the Christie ridge, bending more to the eastward until the coal measures cross the valley of Pincher creek near the southeast corner of township 5, range 1; thence taking a northeasterly course until finally cut off by a fault about 2½ miles east of Pincher creek. A section across these parallel strips of rocks will give a periodic repetition of the same measures.

Two of the formations at least, the Kootenay, and the Crowsnest volcanics, have been shown to be thinning out rapidly towards the south and east.

The volcanics have a thickness of about 1,500 feet between Ma butte and the railway just west of Coleman, and their thickness in the western part of the South Fork district is close to 1,000 feet, but 15 miles to the eastward they are not over 150 feet thick, and to the southeast they disappear altogether.

Economic Geology.

COAL

In the area examined, coal occurs only in the upper third of the Kootenay formation, the coal measures being something over 200 feet thick in the sections measured. The Kootenay coal measures in this area are not as thick as they are in some localities to the north and west of here.

North Kootenay Pass Area

The coal in this area is staked by the Premier Coal and Coke Co., of Fernie, B. C., and is the usual type of Kootenay bituminous coal. The coal measures occur as two curved but parallel bands, repeated by faulting, and overturned, in some cases as much as 150° to the east. The dips range from 30° to 70° west. Southeastward from the pass the measures run about 3 miles, until cut off by a fault at a little cirque lake immediately northeast of the glaciated mountain known as MacCarthy Peak. Northward they are reputed to run 5 miles or more. Owing to the fact that probably not all the seams were seen, a definite statement cannot be made as to their number; there appear to be four or five, the thickest seen containing 9 feet of workable clean coal; this being in the so-called 'Eastern series'. The 'Western series' follows the boundary of the Cretaceous basin closely, and is immediately under the great boundary overthrust, in fact, on MacDonald creek it is concealed under the overthrust limestones. Three seams of coal were seen at one exposure of this series, none over 4 feet thick.

The following analyses (obtained from a blue-print kindly furnished by the company) show the character of the coals:—

Sample No.	Seam No.	Location.	Distance in from surface.	Moisture.	Volatile matter.	Fixed carbon.	Ash.
1	1	Eastern series, 200 yds. S. of S. Fork river..........	150 ft.	1·80	27·80	61·90	8·50 Good coking qualities.
2	2	Eastern series, S. of MacCarthy Peak.	30 ft.	1·13	19·83	61·31	17·73
3	5	Eastern series, ½ m. N. of S. Fork river.	15 ft.	4·57	34·48	55·82	5·13
4	1	Western series, north bank South Fork river	12 ft.	3·49	27·06	59·10	10·34
5	3		Stripping...	1·78	27·30	59·64	11·28
6	4		Stripping..	6·99	30·38	50·94	11·69

Hastings Ridge.

The coal measures on Hastings ridge are owned by the Head Syndicate, and are the southward extension of the Coleman series. This band is faulted off within a few score yards after crossing Link creek. The coal seams have been opened up on the north bank of Link creek, but were not examined by the writer. The probabilities are that the Coleman seams will also be workable in this district. The coal seams dip westward about 60°.

Long Mountain.

The Mutz and the Blairmore outcrops of the Crowsnest pass are continued in two parallel, gradually approaching fault blocks on Long mountain, extending to the valley of the South Fork river and forming part of the western limb of the Turtle Mountain anticline. The end of the mountain overlooking the valley is much broken by faulting, and the Mutz ridge of coal rocks is here cut off. It is probable that the coal in the end of this mountain for a distance of about half a mile north of the South Fork river cannot be worked profitably owing to its complex structure. Northward toward Turtle mountain, these zones should prove of value, and the eastern one is worked at Blairmore at the present time. Sections of the coal measures of these two series were not seen, but the following information regarding the seâms was kindly furnished by Mr. M. J. Rhinas, of the Coal Securities, Ltd:—

Blairmore Zone.

No. 1. Seam (top seam; under conglomerate)—

Coaly shale	3 feet.
Coal	18 feet.
Total	21 feet.

No. 2. Seam—
Coal 6 feet.

No. 3. Seam—
Thin, poor and shaly.

No. 4. Seam—
Like No. 3.

No. 5. Seam—
Coal 8 feet.

Mr. Rhinas states that the Mutz series is similar, except that No. 1 seam as 14 instead of 18 feet of coal.

Maverick Mountain.

Coal measures outcrop on Maverick mountain, on the east side of Webb creek. They are part of the eastern limb of the Turtle Mountain anticline. Their structure is as yet not understood, but it is known to be complex, and part of the coal has been eroded away from the top of the mountain near its southern end. A section of the northern extension of these beds was made by W. W. Leach, in 1902, on Byron creek.[1]

He found 101 feet 9 inches of coal in eleven seams (some of which probably extend southward) but it is possible that there is a duplication of the coal seams here.

Canon Creek and Carbon Hill.

The property on Canyon creek is held by the north Kootenay Pass Coal and Coke Co., Ltd. Two bands of coal measures are found in this area, the structure of which is complex. The Turtle Mountain anticline is here rapidly plunging southward, and its disappearance is accompanied by more or less faulting. However, the southern band of coal measures contains several good seams of coal, and is apparently fairly undisturbed. Starting at a fault in the southwest ¼ section 7, township 6, range 5, west of the 5th, this band runs diagonally across the southwest corner of section 8, into the northwest ¼ section 5, where it crosses Canyon creek. Thence it turns easterly to the line between sections 4 and 5, where a sharp turn, probably accompanied by faulting, swings it north into the southwest ¼ section 9, where, after another easterly twist, it is offset by a fault. The surface displacement of this fault throws the coal north about half a mile, to the west branch South Fork river, from where it follows diagonally up the northwest face of Carbon hill, turns round the point of the hill, and crosses the south branch South Fork river in section 10, township 6, range 3, and is finally cut off by a fault in the southwest ¼ section 11.

A compiled section, measured partly on Canyon creek, and partly on a small tributary to it from the east, gave the following thicknesses for the coal measures:—

(The section reads downward, in natural sequence).

[1] W. W. Leach, Annual Report Geol. Surv., Can., vol. xv, 1902, p. 175A.

1.	Massive cherty conglomerate		21 feet.
2.	*Coal*		4 feet 2 inches.
3.	Grey shale		2 feet 6 inches.
4.	*Coal*		7 feet 0 inches.
5.	Concealed	approx.	31 feet 4 inches.
6.	*Coal*	"	4 feet
7.	Concealed	"	23 feet 4 inches.
8.	*Coal*		3 feet 0 inches.
9.	Concealed		78 feet 5 inches.
10.	*Coal*		3 feet 7 inches.
11.	Concealed		21 feet 8 inches.
12.	*Coal*		0 feet 8 inches.
13.	Concealed		25 feet 4 inches.
14.	*Coal*		0 feet 6 inches.
	Total		226 feet 6 inches.
	Total coal		22 feet 11 inches.

A section near the corner post of section 5–6–3 gave similar relations. Northwest of this corner post, two other coal seams are exposed. It is probable that they are in their present position due to faulting or folding. On the south branch South Fork river, a somewhat similar section gave 222 feet of measures with a total of 11 feet of coal in four seams.

Beaver Mines

The band of coal measures which is worked at Beaver Mines runs northwestward from there to the vicinity of Burmis, in the Crowsnest pass, a distance of some 9 or 10 miles. Southeastward it runs about 6 miles to where it is cut off by faulting, south of Bovie lake. Parallel to this band, and about a mile west of it, a similar series of coal measures, repeated by faulting, runs from the Crowsnest pass to the valley of Pincher creek in the southwest corner of township 5, range 1, west of the 5th meridian, maintaining a southwesterly direction to this point, where it turns east and northeast for 2 miles. It, too, is cut off by faulting at its southeastern end, and is also concealed by a fault for a portion of its length between Crowsnest and South Fork rivers.

At Beaver Mines, the Western Coal and Coke Co. are mining a 7 feet 4 inches seam, dipping 30° to 32° southwest. They have openings on this seam on both sides of the valley of Beaver creek. Twelve feet below this seam is a 2 feet 6 inch seam of coal, and about 40 feet below this, a 1 foot 6 inch seam.

The western series, where it crosses Beaver creek about a mile west of Beaver Mines, shows 27 feet of coal in four seams, none over 5 feet thick, all within 151 feet of the top of the Kootenay. These beds also dip about 30° southwest.

Mill Creek

The same band of coal as that mined at Beaver Mines is worked on Mill creek by Mr. Albert Link, by means of a slope and horse-whim. The seam at the surface shows 6 feet of coal with some shaly partings. The coal hoisted from the mine is a firm, hard, bituminous variety and gives large lumps that do not disintegrate as rapidly as most of the Kootenay coals of the area. Some openings have been made where the western series crosses about a mile farther up Mill creek, but they were not visited.

Christie Ridge

The western band of coal measures of Beaver and Mill creeks is continued

in the Christie ridge, as already outlined. It is mined at the Good mine, operated on a small scale by Mr. J. G. Good, situated in the southwest ¼ section 11, township 5, range 1, west of the 5th meridian. Here there is said to be a seam averaging 7 feet 6 inches, with some smaller seams underneath, one about 4 feet thick. This mine was not visited.

CLAY AND SHALE

As several of the formations of the district are possible sources of plastic material, they will be treated under the headings of each formation, beginning with the oldest.

Fernie Shales.—Several bands of clay shale occur in the Fernie formation that, so far as superficial tests show, would make common brick perhaps by the wet-mud process, and almost surely by the dry-press method. A most unpromising looking band of Fernie shale is made into a dry-press brick at Blairmore[1]. and shales of equal value no doubt occur in this southern district. The Fernie will probably not furnish refractory shales.

Kootenay Formation.—Some of the shales of the lower Kootenay, as they are quite similar to those of the Fernie, would furnish a similar grade of material.

Dakota Formation.—Near the top of the Dakota are some bands of fine shale, and occasionally a few thin seams of plastic clay. While it is improbable that any of these bands are refractory, some of them may be useful for the lower grades of clay products.

Benton Formation.—The Benton beds are nearly wholly a fine clay shale, and are of prospective value as a source of material for common brick manufacture.

A bed of light grey plastic shale outcrops in the Benton measures exposed on Jackson creek, about one-fourth mile from its junction with the South Fork river. This bed, altough not well exposed at this outcrop, appears to be about 4 feet thick, and dips 35° southwest. Less than one-fourth mile upstream the plastic shale is repeated by folding, and dips 65° southwest, the strata forming a syncline overturned to the northeast. At this exposure is a well defined 4- to 5-foot seam of white to light grey, slightly yellowish stained, fine plastic shale between walls of dark grey fine fissile clay shale.

These two outcrops have been sampled by Mr. D. Diver, of Calgary, and his samples have been subjected to tests by Prof. Edward Orton, jr., of Ohio State University. Mr. Diver kindly furnished the writer with a copy of Prof. Orton's report, wherein he sums up his conclusions by saying: 'It is my judgment that with competent management a mixture of these two clays can be made the basis of a successful face brick industry, and a successful industry for stoneware and similar heavy pottery'.

Allison Formation.—There are several bands of light greenish white plastic shales in the Allison beds, notably on Mill creek, just south of the railway about 1½ miles from its mouth, and near the base of the Allison beds where they are again repeated by faulting, on Mill creek in the northwest ¼ section 11, township 5, range 2, west of the 5th meridian. These bands, especially the ones near the railway trestle which are readily accessible to transportation, are well worth prospecting.

LIMESTONE

Limestone occurs plentifully on South Turtle mountain, and in a 20-foot band in the Dakota, crossing the South Fork river less than half a mile below

[1] Ries and Keele, the Clay and Shale Deposits of the Western Provinces, Geol. Surv., Can., Memoir No. 24-E, 1912, p. 115. (Here the shale called Kootenay should be named Fernie).

the mouth of Jackson creek. This latter, being accessible, would no doubt furnish quicklime on burning, and could supply a limited local demand.

PAINT ROCK

Some of the brilliant red and purple bands of the upper Dakota may be suitable for paint rock. They occur in various localities, notably at the lower canyon of the west branch South Fork river, just above its junction with the south branch. The beds here have been worked as an iron claim, but as they are merely ferruginous and rather siliceous shales, the chance of their ever furnishing a supply of iron ore is very remote.

SAND AND GRAVEL

Should local demand require it, the river terraces bordering the larger streams will doubtless furnish sand and various sizes of gravel, on screening.

OIL AND GAS

Borings have been made for oil in two places in the district. A diamond drill hole was put down to a reported depth of about 2,000 feet on the west branch South Fork river, about 3 miles above Lost creek. Further facts about this hole are not known, but evidently no quantity of oil was obtained. On the south branch South Fork river, at the locality known as Kelly's Oil Well, some 8 miles above the junction of the west and south branches, a plunger drill hole has been sunk to a reputed depth of 1,500 feet. From this hole escapes a small flow of gas, and this gas, which has a sickish odour, not unlike gasoline, can be lighted with a match, and burns with a yellow, smoky flame. Both these holes were started some distance above the base of the Allison, and have not penetrated through the Benton shales, from which the gas probably comes.

The Canada West Oil Company, of Victoria, B. C., is engaged in prospecting for oil with a diamond drill on the south branch South Fork river, in the mountains about 3 miles east of the Continental Divide. It is intended to continue the hole to a depth of 2,000 feet, should no oil be found nearer the surface. A hasty visit was made to the scene of the boring, but as the rocks are obscured by forests in the valley, not much could be learned of the structure of the region, though the beds appear to have a low westerly dip, and seem to be limestones. The relation of these strata to the red beds of the North Kootenay pass has not been determined, but it is thought that they are younger.

THE SILURIAN AND DEVONIAN SECTION OF WESTERN MANITOBA

(*E. M. Kindle*)

Introduction.

The geology of Manitoba well illustrates the close interrelationship which often exists between palæontology and geology. Upon the determination of the chronologic relations of the faunas the geologist must base, almost wholly, his deductions regarding the stratigraphic and structural features of this region. The prospector, the mining engineer, or the capitalist who is engaged in developing the mineral resources of the Province is likewise dependent in an equal degree for any comprehensive understanding of the relation, distribution, and depth of any horizon of economic value upon the study of the fossils. Thus in this region the collection and study of the fossils, which to the layman often appears to be wholly an academic or eccentric occupation without practical value, must precede the answer to such vitally practical questions as the source of the artesian water used by the city of Winnipeg, and the probable extent and distribution of one of the most valuable gypsum deposits in America.

The limestones throughout northern Manitoba lie so nearly horizontal that inspection of individual outcrops even where these are extensive, gives no clue to the general inclination and strike of the strata. The outcrops of bed-rock are generally far apart, and as a rule, expose only a few feet of strata. The faunas, however, have shown that the limestones between Lake Winnipeg and the west side of Lake Winnipegosis, represent rocks of Ordovician, Silurian, and Devonian age. Several distinct formations have been discriminated in these limestones. The relative age or order of superposition and distribution of these formations as determined by the fossils, indicates that they have a gentle westerly dip of a few feet per mile.

The excellent work of Tyrrell[1]—and Whiteaves[2]—in northern Manitoba has made known the broader features of the geology and palæontology of the region.

Since the earlier work was done, the discovery of a bed of gypsum 50 feet or more in thickness, in the Silurian rocks, has made a more detailed study of the stratigraphy of these beds desirable. The earlier work has laid a secure foundation for this and for a more detailed study of the successive types of Silurian and Devonian faunas which entered this region, and the various kinds of rocks which are correlated with these successive invasions. In the very brief time at my disposal for field work, it has been possible to make only a beginning in this work.

Topography.

The Palæozoic rocks of northern Manitoba form the floor of a lowland about 25 miles in width, which extends from the area of crystalline rocks bordering

[1] Tyrrell, J. B., Report on Northwestern Manitoba, with portions of the adjacent districts of Assiniboia and Saskatchewan: Geol. Surv. of Can., part E, vol. v, 1889-90-91 (1893).

[2] Whiteaves, J. F., The Fossils of the Devonian rocks of the islands, shores, or immediate vicinity of Lakes Manitoba and Winnipegosis, Can. Geol. Surv., Cont. to Palæontology, vol. I part IV, pp. 255-359, pls. XXXIII-XLIV, 1892.

the eastern shore of Lake Winnipeg to the escarpment along the eastern face of Duck and Porcupine mountains. Nearly all of this lowland lies between 800 and 900 feet above sea-level. The escarpment of Cretaceous rocks, the western border of this lowland plain, rises abruptly 1,400 or 1,500 feet above it. Extensive but shallow depressions in the lowland are occupied by the three large lakes of northern Manitoba. This lowland has, for the most part, an approximately level surface. The mantle of glacial drift conceals most of the inequalities in the surface which probably existed in pre-Glacial times. A few of these are sufficiently prominent, however, to have escaped obliteration by the drift. The harder beds of limestone have developed, in some areas, considerable cliffs. The cliffs at Point Wilkins, which rise about 80 feet above the surface of the lake, represent, perhaps, the maximum development of these. The Winnipegosan dolomite also gives rise, locally, to cliffs 30 or 40 feet in height.

Perhaps the most interesting topographic features of the region are those connected with the gypsum beds north of Partridge Crop lake. Here, the only bed-rock appearing at the surface is gypsum. These beds show well developed 'karst' topography. Innumerable sink holes or 'dolines' and miniature blind valleys give the surface a highly irregular and intricate character. These very soft beds of gypsum are the only Palæozoic rocks which have resisted erosion sufficiently to remain above the adjacent flat swampy drift-covered plain. The crests of the gypsum ridges rise 20 to 40 feet above the adjacent swampy plain. The removal of the hard limestone which must originally have overlain them, and the synchronous development of low hills and knolls from the soft gypsum beds, represents an unusual and striking phenomenon of erosion. Mr. R. W. Brock has suggested to the writer that the removal of the limestone may have been accomplished through the 'plucking' of glacial ice.

General Geology.

The several formations which have been recognized in the Silurian and Devonian rocks of western Manitoba, are indicated in the following table, together with a characteristic or zonal fossil of each:—

Table of Formations.

Formation name.		Character of beds.	Zonal fossils.
Devonian	Manitoban limestone	Chiefly non-magnesian light grey limestones	*Athyris fultonsis* zone. (Upper part of Manitoban.) *Cyrtina hamiltonensis* zone. (Lower part of Manitoban).
	Winnipegosan dolomite	White or cream-coloured dolomite.	*Stringocephalus burtoni* zone.
	Elm Point limestone	Buff or grey argillaceous limestone.	*Atrypa reticularis* var. a zone.
Silurian	Stonewall limestone	Hard light grey or drab dolomitic limestone.	*Leperditia hisingeri* zone.
		Gypsum (local beds).	Barren.
		Buff dolomitic limestone.	*Conchidium decussatum* zone.

Silurian.

Conchidium Decussatum Zone.—The Silurian rocks of the Manitoba section consist chiefly of magnesian limestones which have heretofore been called the 'Niagara limestones'[1]. The fauna of these dolomites differs in a striking manner from the fauna of the New York limestone, formerly called Niagara, and clearly represents a faunal province quite different from that of the western New York Niagara. We do not appear justified in using the name Niagara for beds both lithologically and faunally so unlike those to which the name was applied in western New York. For this reason a local name will be used for the Silurian beds of the section. It is proposed to use the name Stonewall limestone for all of the Silurian beds between the Ordovician and Devonian terranes on the east side of Lakes Manitoba and Winnipegosis. The name is taken from the town of Stonewall where the fossiliferous beds are better exposed than at any other locality known to me. No section is known which exposes the whole of the Silurian. The quarry section of Stonewall exposes the lower portion of the Silurian beds which is shown by the following section taken at the quarry on the north side of Stonewall:—

Stonewall Section.

Light cream-coloured or nearly white magnesian limestone, mostly heavy-bedded	12 feet.
Pink thin-bedded shaly magnesian limestone	1 foot.
Heavy-bedded buff vesicular limestone with poorly preserved *Favosites* and other fossils which are chiefly responsible for the numerous small cavities	6 feet.

The Ordovician beds at the base of the Stonewall limestone do not outcrop in the vicinity of Stonewall, but are well exposed at Stoney mountain, a few miles to the southeast. Dowling[2] has given the name Stoney Mountain formation to the Ordovician beds at Stoney mountain. The upper part of these beds consists of dolomitic limestone, but it differs noticably in colour from the dolomitic limestones of the Stonewall formation. The latter is very light buff, almost white in colour, while the Stoney Mountain limestone is a dark buff or pale lemon colour.

The faunas are wholly unlike. The fauna of the Stoney Mountain formation includes a large fauna with such characteristic Ordovician fossils as—*Rhynchotrema capax*, *Platystrophia lynx*, *Orthis testudinaria*, and *Dinorthis proavita*, which has been considered of Richmond age[3].

The fauna of the Stonewall limestone shows no evident relationship to that of the Stoney Mountain formation which precedes it in the section. The beds exposed at Stonewall have afforded the following species: *Aphyllostylus gracilis* Whiteaves, *Favosites gothlandicus* Lamarck, *Favosites asper* d'Orbigny, *Dinobolus* cf. *conradi* Hall, *Strophomena* sp., *Conchidium decussatum*[4], *Modiolodon* sp., *Murchisonia* sp., *Pleurotomaria* sp., *Spyroceras meridionale* Whiteaves, *Tripleuroceras robsoni* Whiteaves, *Cyrtoceras*? *cuneatum* Whiteaves, *Trochoceras insigne* Whiteaves.

[1] Tyrrell, J. B., Report on Northwestern Manitoba, with portions of the adjacent district of Assiniboia and Saskatchewan: Geol. Surv. of Can., part E, vol. v, 1889-90-91 (1893) p. 163E.

[2] Dowling, D. B., Annual Report, Geol. Surv. of Can., vol. xi. p. 46F, 1900.

[3] Geol. Surv. of Can., Annual Report, vol. xi, part F, pp. 48–54, 1900.

[4] *C. decussatum* is included on the authority of J. B. Tyrrell.

The other species occur in the collections studied by Whiteaves and that made by the writer.

This fauna has a late middle Silurian aspect but it contains no guide fossils which would justify positive correlation with any particular formation of the New York Silurian. The presence of *Dinobolus* suggests that it may be the Manitoba equivalent of the Guelph fauna. The sharp contrast which this fauna appears to show with the fauna of the same formation 80 or 100 miles to the northwest of Stonewall may be due to the few and small collections which have been made from the comparatively inaccessible section of this north rly region. *Conchidium decussatum* is the only fossil known to be common to this lower part of the Silurian in both these areas, and it may be considered the guide fossil of this part of the formation.

Gypsum Beds.—The light buff magnesian limestone of the lower part of the Stonewall limestone is succeeded above by white gypsum in the region west of St. Martin lake. It is very probable, as pointed out elsewhere in this report, that this succession holds in various other districts underlaid by this formation. At Gypsumville, the surface exposures and core drill records, together, show a maximum thickness of about 58 feet of white gypsum. About 20 feet of this thickness is exposed in the gypsum quarries. The gypsum lies in thin strata separated sometimes by thin films of argillaceous material of paper-like thinness. Nearly all of the gypsum exposed is pure white in colour, but at one or two points, interbedded white and pink or reddish gypsum occurs. At the extreme end of one of the quarries, the white gypsum passes laterally into reddish-brown beds containing a large per cent of argillaceous material. If the exposure extended further in this direction it is probable that the ferruginous argillaceous gypsum would be seen to pass along the bedding planes into red magnesian shale or limestone. The core drill records indicate that the beds immediately below those exposed at the surface vary considerably in short distances. One drill hole made near the centre of the quarry of the Manitoba Gypsum Company is said to have passed through 40 feet of white gypsum below the quarry floor. A drill core made near the point where the quarry beds pass into reddish gypsum, shows about half the core to a depth of 50 feet to be composed of argillaceous matter interstratified with gypsum—the two occurring in alternating strata one-fourth inch to 2 inches in thickness. Below 50 feet, the proportion of argillaceous matter increases, and the gypsum shows only as very thin bands one-fifth of an inch or less in thickness.

Leperditia Hisingeri Zone.—The beds which follow the gypsum beds have not been seen in actual superposition. The nearest known outcrops of the next higher beds in the Stonewall formation lie some 8 miles to the westward of the gypsum quarries. These have furnished a variety of *Leperditia hisingeri* and one or more species of *Stropheodonta.* Exposures of this highest division of the Silurian limestone of Manitoba, occur along the railway a few hundred yards south of Fairford station, and on the south bank of the Fairford river near its head. The outcrops at these points show a very hard light-coloured dolomitic limestone in which no fossils were found. A third locality at which this higher Stonewall limestone was examined yielded no fossils, and it is not certainly known what the character of the fauna of these upper beds is in the vicinity of Fairford. It is probable, however, that it is similar to the ostracode fauna collected by Tyrrell[1] at Long Point which appears to belong at this horizon. The prominence in this horizon of *L. hisingeri* suggests designating it the *L. hisingeri* zone.

The highest beds of the Stonewall limestone which have been seen, are exposed in a prospect hole about 2½ miles southeast of the head of Fairford river, on the east side of the wagon trail from Fairford to Elm creek and Moosehorn bay. The drift cover along the wagon trail in this vicinity is very thin and contains an

[1] Geol. Surv. of Can., Palæozoic Fossils, vol. III, part F, p. 289, 190.A

abundance of reddish brown pebbles and small brown rock fragments, suggesting a hard red shale as the underlying formation. A prospect hole 8 feet deep shows, however, that these reddish pebbles have been derived from an argillaceous magnesian limestone. The ordinary colour of this limestone a few feet below the surface, appears to be a cream or dull grey. The upper part of the excavation shows a bright red or brown colour which has extended downward in a highly irregular fashion, from a few inches to a few feet. It is probable that this bed of red argillaceous limestone of variable thickness, represents the 'red and other shales' of Tyrrell's 'Lower Devonian' which 'have not been clearly defined[1]'. The lowest horizon of the Devonian which I have been able to recognize in this region is represented by fossiliferous limestones on the lake shore a short distance to the southwest of this locality and these reddish limestones are believed to be Silurian. It is impossible to give any very close estimate of the thickness of the Silurian rocks here included under the name Stonewall limestone, owing to the widely scattered character of the various outcrops which represent the different horizons of the Silurian, but it is believed that the total thickness of the Stonewall formation is not less than 250 feet.

Devonian.

Elm Point Limestone.—The Devonian rocks are referable to three distinct formations. The oldest of these has not hitherto been distinguished from the one succeeding it, although various outcrops which represent this lowest formation have been mentioned by Tyrrell[2]. Each of these three formations is characterized by well-marked lithologic and faunal differences. The oldest of these terranes is well exposed on the east shore of Lake Manitoba, 8 miles south of the head of Fairford river at Steeprock point. At this locality, the Devonian limestone is exposed in wave-worn cliffs having a maximum height of not more than 20 feet. The rock is a light buff or cream coloured limestone which effervesces freely in acid. The limestone is thin bedded, the strata being mostly 1 inch to 4 inches thick This limestone differs markedly in its magnesian content from the highly magnesian limestones of the Silurian terranes below, and the Winnipegosan dolomite above. It is proposed to call this lowest formation of the Devonian which separates the Winnipegosan dolomite from the Stonewall limestone, the Elm Point limestone. The name is derived from a prominent projecting point of the coast line, a short distance south of the exposures just described. The thickness of the formation has not been determined, but it is not less than 25 feet. This formation is exposed 75 miles to the southeast of Elm point near Oak Point village. Near the church, northeast of Oak Point, 2½ miles, a quarry exposes 5 feet of light buff, thin-bedded limestone. The strata are 2 inches to 4 inches thick, with irregular surfaces. The following fauna was collected at this point:—

Productella spinulicosta Hall.
Atrypa reticularis Linn. var. a.
Schizophoria striatula (Schlotheim).
Euomphalus cf. subtrigonalis Whiteaves.
Raphystoma tyrrelli Whiteaves.
Callonema cf. lichas Hall.
Pleurotomaria? sp.
Orthoceras sp.
Proetus mundulus Whiteaves?

[1] Can. Geol. Surv., Annual Report, New Series, vol. v, part I, p. 200E, 1893.
[2] *Ibid.*, p. 194E.

This is the same fauna which characterizes the beds exposed at Steeprock point. Collections from Lundyville made by Tyrrell, show a similar congeries of species. A notable feature of this fauna is the absence of *Stringocephalus burtoni*, the abundant and most characteristic fossil of the Winnipegosan dolomite. The absence of this fossil which was looked for with particular care, plainly indicates that this is not part of the fauna of the *Stringocephalus* zone. Its field relations indicate that it belongs immediately below the *Stringocephalus* zone. The most abundant fossil in this fauna is a peculiar variety of *Atrypa reticularis* which may here be designated as *A. reticularis* var. a. The distinctive feature of this new variety is the extraordinary development of the anterior and lateral margins of the valves in inflated extensions which are marked by numerous *bifurcating* plications. This feature, together with the extreme fineness of the striæ on the gibbous portion of the shell, distinguish this form from others which show a tendency to develop flattened extensions of the valve margins. This fauna, which precedes the *Stringocephalus* zone in the Devonian section, may be conveniently distinguished faunally as the *Atrypa reticularis* var. a. zone.

While this fauna appears to be the oldest fauna in the Devonian of Manitoba it is not earlier than middle Devonian. The hiatus between the Silurian and the Devonian is, therefore, indicated by the absence of all of the lower Devonian.

Winnipegosan Dolomite.—J. B. Tyrrell has concisely defined the Winnipegosan dolomite as a 'whitish or light yellow hard, tough, generally compact dolomite containing *Stringocephalus burtoni* and numerous other fossils. It outcrops chiefly on the islands and shores of Dawson bay, and southward to Point Richard on Lake Manitoba'[1]. These hard dolomites are physically quite unlike the non-magnesian or very slightly magnesian limestones of the Elm Point and Manitoban formations which respectively precede and follow them. The presence of the European species *Stringocephalus burtoni* in the Winnipegosan dolomite gives the formation an especial interest. This fossil appears to be confined to this formation, having been found neither above nor below it. Although *S. burtoni* is one of the most abundant fossils in the Winnipegosan dolomite and a common middle Devonian fossil in Europe, it is unknown in the American Devonian south of Canada. It is interesting to note that *S. burtoni* did not enter the Manitoba province with the first invasion of the middle Devonian fauna. The fauna represented by the peculiar variety of *A. reticularis* and *Productella subaculeata* of the Elm Point limestone were its predecessors and it disappeared with the coming in of *Cyrtina hamiltonensis* and its associates which are peculiar to the Manitoban formations. The rich fauna of the Manitoban dolomite has been described by Whiteaves[2]—and listed by Tyrrell.

The character of this fauna is illustrated by the following list of fossils which Tyrrell collected at a single locality on an island 1½ miles north of Whiteaves point in Dawson bay:—

Sphaerospongia tessellata (Phillips).
Favosites gothlandica Lamarck.
Pachypora cervicornis (De Blainville).
Alveolites like *cryptodens* Billings.
Stromatopora bücheliensis (Bargatzky.)
S. hüpschii (Bargatzky).
Ctenocrinus sp.
Spirorbis omphalodes (Goldfuss).
Pinacotrypa marginata Whiteaves.

[1] *Ibid.*, p. 200E.
[2] Geol. Surv. of Can., Contrib. to Can. Pal., vol. I, part IV, pp. 255–359, plates 33–47, 1892

Cystodictya hamiltonensis Ulrich.
Fenestella vera Ulrich.
F. dispanda Hall.
Polypora manitobensis Whiteaves.
Productella subaculeata (Murchison).
Schizophoria manitobensis Whiteaves.
Schuchertella chemungensis (Conrad).
Strophodonta interstrialis (Phillip).
Strophodonta arcuata Hall.
Spirifera fimbriata (Conrad).
Atrypa reticularis Linnaeus.
Pentamerus comis (Owen).
Stringocephalus burtoni Defrance.
Terebratula sullivanti Hall.
Actinopteria boydii (Conrad).
Nucula manitobensis Whiteaves.
Dentalium antiquum Goldfuss.
Pleurotomaria spenceri Whiteaves.
Euomphalus annulatus Phillip.
Platyceras parvulum Whiteaves.
Orthoceras (Thoracoceras) tyrrellii Whiteaves.
Gyroceras filicinctum Whiteaves.
Isochilina dawsoni Jones.
Elpe tyrrellii Jones.
Bronteus manitobensis Whiteaves.
Cyphaspis bellula Whiteaves.
Proetus mundulus Whiteaves.

The gentle westerly declination of the rocks of northern Manitoba brings the consecutive Devonian formations to the surface in successively younger beds which lie always to the west of older beds. The outcrops of the Manitoban dolomite, therefore, lie farther west than those of the Elm Point limestone. The latter formation forms a belt which skirts the eastern shore of Lake Manitoba, and the outcrops of the former would be found immediately west of it did not the waters of the lake intervene. Owing to the absence of islands in the southern half of Lake Manitoba, no outcrops of the Manitoban dolomite are known south of Sifton narrows. At Point Richard, Tyrrell[1] reports the Manitoban dolomite to outcrop in cliffs, which are about on the north and south axis of the lake. To the northwest, outcrops of this formation are not uncommon on the islands, and along the shores of Lake Winnipegosis. Numerous outcrops of the hard, white or cream-coloured sacheroidal dolomite occur about the shores of Dawson bay.

A typical exposure of the Winnipegosan dolomite is shown in the cliff at Whiteaves point, 10 miles east of the mouth of Steeprock river. Whiteaves point is a cliff of white, compact dolomite, with a maximum height of 31 feet above the water, and extends a mile along the shore. Beautifully preserved fossils occur in abundance in this dolomite. Among the common and characteristic forms are *Stringocephalus burtoni* Defrance, and *Gyroceras canadense* Whiteaves. Anothei excellent exposure of the *Stringocephalus* dolomite occurs at Salt point, 4 miles west of Whiteaves point. About 30 feet of white dolomite weathering yellowish are exposed in the cliff here. The fauna includes a considerable number of species, among which may be noted *Sphaerospongia tessellata*

[1] *Ibid.*, p. 193E.

(Phillips), *Columnaria disjuncta* Whiteaves, *Atrypa reticularis* Linn, *Gypidula*, *Stringocephalus burtoni* Defrance, *Kefersteinia subovata*, Whiteaves, and *Paracyclas antiqua* Goldfuss. The exact thickness of this formation is unknown, but it is probably in the neighbourhood of 165 feet.

Manitoban Formation.—The term Manitoban formation as introduced and applied by Tyrrell[1] includes all of the Devonian strata above the Winnipegosan dolomite. These higher beds are chiefly non-magnesian limestones and in their physical appearance present a marked contrast to the dolomitic limestone of the Winnipegosan formation. Nearly all of the known exposures of the Manitoban formation are confined to the shores and islands of Lake Winnipegosis. The lower limestones of the Manitoban are well exposed on Snake island near the southern end of Lake Winnipegosis. This island, as noted by Mr. J. B. Tyrrell[2], is classic ground in western geology, having furnished the collection of fossils made by Prof. H. Y. Hinde, in 1858, which first determined the presence of Devonian rocks in Manitoba.

The sharp dips of 5° or more seen at this and other localities have only local significance. The general dip of the rocks of this region is westerly and amounts to probably not more than 40 feet per mile. Cliffs 20 feet high at the northwest angle of the island expose about 24 feet of grey limestone which lies mostly in strata 6 inches to 8 inches thick. Some of the beds near the middle of the cliff are ripple-marked. One of the large limestone blocks, which has fallen from the face of the cliff, exhibits large clearly moulded ripple marks. The crests of these are 2 feet apart, and rise about 1½ inches above their troughs. The ripples curve slightly in crossing the surface of the limestone. The rock on which they are impressed is a comparatively pure non-magnesian limestone. The surface of the ripple marks shows great numbers of finely comminuted shell fragments. These small fragments of various kinds of molluscan shells, comprise a large share of the material composing the limestone in the middle third of the cliff section in which the ripple marks occur. These broken shell fragments thus strongly supplement the evidences of the large ripple marks in indicating vigorous disturbance by wave action of the sea bottom in which they originated. Beyond this fact, it is perhaps not safe to make any deductions regarding the physical conditions under which these ripple marks were produced. It is clear that the water was of sufficiently moderate depth to permit wave action to agitate the bottom, but it does not follow, on the other hand, that the sea was extremely shallow. Nor is any valid ground afforded for the assumption of beach conditions which the discussion of ripple marks presented in some texts[3] might lead one to make. It has been shown by Mr. A. R. Hunt[4] and others that . . . 'ripple marks occur at much greater depths than is commonly supposed'. Dana[5] has stated that 'ripple marks may be made by the vibration of waves even at depths of 300 to 500 feet'. The unusually large size of these ripple marks suggests water of greater depth than that which develops the ripple marks seen along many beaches. Hunt's observations have shown that thousands of specimens of marine shells are sometimes killed in six fathoms of water by wave action. The same observer has found evidence of much damage to shells living in fifteen fathoms from the same cause[6]. The broken shell material in these limestones might, therefore, have been produced in water a few fathoms in depth. The lime-

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[1] *Ibid.*, p. 199E.

[2] *Ibid.*, p. 163E.

[3] Le Cont states (Elements of Geology, 1888, p. 3a) 'By means of these characteristic ripple marks of shore deposit, many coast lines of previous geological epochs have been determined.'

[4] On the formation of ripple marks: Proc. Roy. Soc., Lond., vol. xxxiv, p. 8, 1883.

[5] Dana, J. D., Manual of Geology, 2nd edition, 1869, p. 665.

[6] *Ibid.*, pp. 8, 12.

stones which immediately follow the ripple-marked beds in the cliff section on Snake island show but little fragmental material, the fossils contained in them being in a good state of preservation. Ripple marks appear to be absent from these upper beds.

The ripple-marked beds of the Snake Island section lie not far above the *Stringocephalus* zone of the Winnipegosan dolomite. Since the dolomite bearing *Stringocephalus burtoni* does not appear in the Snake Island section, the precise distance of the ripple marks above this formation cannot be stated; but they belong near the base of Manitoban formation. The following fossils determined by Prof. J. F. Whiteaves are recorded from the limestones of this formation on Snake island by Tyrrell[1]:—

Cyathophyllum vermiculare var *precursor* Frech.
Alveolites vallorum Meek.
Atrypa reticularis (Linnaeus).
A. aspera Hall.
Cyrtina hamiltonensis Hall.
Schizophoria striatula (Schlotheim).
Poracyclas elliptica Hall.
Raphistoma tyrrelli Whiteaves.
Bellerophon pelops Hall.
Euomphalus subtrigonalis Whiteaves.
Omphalocirrus manitobensis Whiteaves.
Cyrtoceras occidentale Whiteaves.
Gyroceras submamillatum Whiteaves.
Dinichthys canadensis Whiteaves.

To this list may be added *Astraeospongia hamiltonensis* M. and W. The small six-rayed spicules of this sponge occur in large numbers in a band of limestone 8 inches below the top of the cliff on the northwest side of the island. On the evidence of this fauna, these beds were assigned to a middle or upper Devonian horizon by Whiteaves[2].

The stratigraphic equivalent of the limestones seen at Snake island, together with the higher beds of the Manitoban formation, are well exposed in the Dawson Bay district. Dawson bay is a large pocket-like expansion extending west and south from the northern end of Lake Winnipegosis. This bay is excavated wholly in Devonian rocks and the numerous exposures on its islands and shores and along the Red Deer river, show most, if not all, of the Devonian section. This makes Dawson bay the most favourable region in which to study the upper part of the Devonian section of Manitoba.

The Manitoban formation is exposed in several cliffs and points to the north of the mouth of Steeprock river, within a few miles. One of the best sections is exposed at Point Wilkins which is 4 miles north of Steeprock river, and rises 80 feet above the lake. The cliffs here expose the following beds of the Manitoban formation:—

Point Wilkins Section.

b. Light grey fine-grained, thin-bedded limestone, some beds breaking with conchoidal fracture....................................	45 feet.
a. Light ash grey argillaceous limestone...........................	35 "

[1] Geol. Surv. of Can., Annual Report, New Series, part E, vol. v, 1889-90-91 (1893), p. 163E.
[2] Geol. Surv. of Can., Contrib. Can. Pal., vol. I, part IV, pp. 255-263, 1892.

The fauna in the lower division (a) of the section is represented by the following species:—

Atrypa reticularis Linn. . . . . a.
Ambocaelia umbonata vel.
Sp. (*Martinia*) *richardsoni* . . . . a.
Euomphalus subtrigonalis Whiteaves. . . . . r.
Orthoceras sp.
Paracyclas elliptica var. *occidentalis* Billings. . . . . c.

The upper division (b) of the section holds a fauna quite unlike that of the lower as the following list of species will indicate:—

Athyris fultonensis (Swallow). . . . . a.
Leptodesma demus Hall var. . . . . c.
Euomphalus sp. undet. . . . . r.

The small fauna shown in lot (b) is believed to represent the latest Devonian fauna in the region. Tyrrell[1] records another species *Cypricardinia planulata* from this fauna at a locality north of Steeprock river.

The great abundance of *Athyris fultonensis* in certain strata of this highest known division of the Devonian section, suggests that it may be conveniently designated the *Athyris fultonensis* zone. This fauna has been found on Rose island in Swan lake south of Dawson bay by Tyrrell[2]. The lower part of the section at Point Wilkins represents a lower portion of the Manitoban formation, various parts of which are represented by these basal beds of the cliffs, the beds at Snake island, and several outcrops along the Red Deer river below the Long rapids. One of the Red Deer river outcrops at which fossils are abundant, is a low knoll of limestone one mile below the Long rapids. The summit of this limestone knoll rises 22 feet above the river. It is about 300 feet in diameter, roughly circular, and surrounded by a flat alluvial plain. A saline spring which issues from near the summit of the knoll, has kept the surface free from vegetation save for a small salt-water loving plant. The following fossils were collected from this exposure (station 15):—

Stropheodonta arcuata Hall.
Atrypa reticularis (Linnaeus).
Atrypa missouriensis Miller?
Schizophoria striatula (Schlothiem).
Cyrtina hamiltonensis Hall.
Martinia cf. *richardsoni* Meek.
Paracyclas elliptica var. *occidentalis* Hall and Whitfield.
Paracyclas antiqua (Goldfuss).
Modiomorpha cf. *parvula* Whiteaves.
Mytillarca sp.
Bellerophon cf. *pelops* Hall.
Euomphalus (*Straparollus*) cf. *annulatus* Phillips.
Raphistoma tyrrellii Whiteaves.
Euomphalus cf. *cyclostomus* Whiteaves.
Proëtus mundulus Whiteaves.

In this and most other fannules of the lower part of the Manitoban beds

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[1] *Ibid.*, p. 183E.
[2] *Ibid.*, p. 189E.

Cyrtina hamiltonensis is a conspicuous species. It is one of those species which as all the collections indicate, appears in the section after *Stringocephalus burtoni* disappears from it. We may, therefore, conveniently designate the lower part of the Manitoban fauna as the *Cyrtina hamiltonensis* zone. This is the faunal zone lying between the *Stringocephalus* and the *Athyris fultonensis* zones.

Below station 15, about three-fourths of a mile, an outcrop in the north bank of Red Deer river shows beds of somewhat different type from those composing most of the Manitoban formations. The section exposed here follows:—

Section on Red Deer River 1½ miles above mouth.

c. Blue argillaceous shale, fossils abundant..............................	8 feet.
b. Grey argillaceous and magnesian limestone........................	6 "
a. Light grey limestone with obscure bedding.........................	10 "

Beds b and c of this section contain an abundant fauna. The following species were collected from these:—

Cladopora cf. *dichotoma.*
Reptoria cf. *stolonifera.*
Productella spinulicosta.
Atrypa reticularis Linn.
Atrypa hystrix var. *occidentalis* Hall.
Chonetes cf. *logani* var. *aurora.*
Chonetes sp. undet.
Chonetes n. sp.
Spirifer sp.
Cyrtina hamiltonensis.
Martinia cf. *richardsoni.*
Anoplotheca n. sp.
Paracyclas antiqua.
Paracyclas ellipica var. *occidentalis.*
Modiomorpha compressa Whiteaves?
Porcellia manitobensis.
Bellerophon pelops Hall.
Actinoceras hindi Whiteaves.

Economic Geology.

The mineral resources of economic value occurring within the area examined include limestone, gypsum, sand and gravel, and saline waters.

LIMESTONE

Five belts of limestone trending north and south, which differ from each other in varying degrees, are crossed in going westward from Lake Winnipeg to the west side of Lake Winnipegosis. The generally light cover of drift in the inter-lake region renders the limestone easily accessible there; but south of the lakes the great increase in thickness of superficial deposits buries them beyond the reach of ordinary quarrying operations.

The Silurian and Ordovician limestones which lie to the east of Lake Manitoba approach each other in physical features, the former being lighter coloured than the upper formation of the Ordovician, which is a buff or lemon-coloured rock. Both are magnesian limestones. They have been used extensively for the manufacture

of lime, crushed stone, and dimension stone for rough masonry and foundation work. The principal quarries in these limestones are located at Stonewall and Stony mountain. The basal limestone of the Ordovician, called the Cathead limestone, is a comparatively soft magnesian limestone which has been used for structural purposes to some extent. The nearest outcrops of this rock to Winnipeg occur in the bank of Red river at Lockport.

The basal limestone of the Devonian limestone series lies at or near the surface along the east side of Manitoba lake south of Fairford river. It is almost or quite free of magnesia at some localities where it can probably be successfully used for Portland cement.

A bed of hard, white to cream-coloured dolomite composes a considerable part of the lower half of the Devonian section. This is a very tough, often vesicular, rock which makes a considerable proportion of the outcrops about the shores and islands of Lakes Manitoba and Winnipegosis. It has not, so far as known, been commercially utilized.

The most westerly of the limestone belts of the region forms numerous outcrops and such conspicuous cliffs as Point Wilkins, along the western shore of Lake Winnipegosis. This limestone differs from the others mentioned in being a non-magnesian limestone. But little if any commercial use has as yet been made of it. It is, however, one of the valuable mineral assets of the region, and will in the future doubtless be extensively utilized for lime and cement. The upper 40 feet of the limestone in the Point Wilkins cliffs on Dawson bay is a very pure limestone which should make a high grade cement or lime. An abundant supply of shale is available for the manufacture of cement a few miles to the westward of Dawson bay in the basal beds of Porcupine mountains. An abundant supply of the raw material, combined with the transportation facilities afforded by the Canadian Northern, offers strong inducement for the development of the cement industry in the Dawson Bay region.

GYPSUM

Location, Development, and Character.—The extensive gypsum deposits located 10 or 12 miles northwest of Lake St. Martin have been known and worked for some years. The product until recently was shipped by tramway and boats to the south end of Lake Manitoba, thence by rail to Winnipeg. The expensive rehandling involved in this method of shipment has been eliminated by the building of a branch line of the Canadian Northern from Winnipeg to the quarries, a distance of 180 miles. With the completion of the railway these deposits became, from the commercial standpoint, one of the most important gypsum fields on the continent, The considerable thickness of the bed and peculiar manner of occurrence of the gypsum as hummocks or low knolls in a flat country and without any overburden of rock reduces the cost of quarrying to the minimum.

The surface of the gypsum deposits is deeply pitted with sink holes which carry much of the drainage into subterranean channels. The overburden of soil and weathered gypsum varies from 3 to 4 feet in the bottom of some of these sinks to a few inches over the summits of the ridges between them.

The gypsum lies in thin strata which are sometimes separated by films of grey shale. These films are generally too thin to have any deleterious effect on the otherwise white stratified gypsum. In a limited area at the north end of the quarry some interbedded pink and white gypsum occurs. At the extreme south end of the present excavation, the white gypsum beds pass laterally in a short distance into red and brownish highly argillaceous gypsum, thus suggesting that in that direction the deposit may become largely shale in a short distance. Numerous small anticlinal arches 15 to 30 feet apart have been developed in the

gypsum beds. The quarry showed a face of 16 feet at the time of my visit. A newly constructed drainage ditch will make available 8 feet more of gypsum, thus giving 24 feet of workable gypsum above drainage level in the quarry. The total thickness of good white gypsum shown by the core drill in the north part of the quarry, as reported by the foreman, Mr. T. Brommell, is 58 feet.

A core taken at the south end of the quarry shows much red argillaceous material like that in the quarry face at the south end.

The gypsum is blasted with light charges of powder and loaded into cars with a steam shovel. The output is about 100 tons per day. The gypsum is shipped to the mills at Winnipeg where it is calcined and ground.

The principal holdings of gypsum land are those of the Manitoba Gypsum Company and the Dominion Plaster Company, at Gypsumville. The gypsum beds are exposed continuously for more than one-fourth mile in the quarry of the former company. The Dominion Plaster Company has a mill under construction in Winnipeg with a capacity of 400 tons per day, and will probably begin manufacturing plaster during the coming summer.

Areal Distribution.—Exposures of gypsum have been found over an area of about 8 square miles in the Gypsumville district. The quality, drainage, and other physical factors will probably permit of the development of only a fraction of this area.

There is but little direct information available concerning the distribution of the gypsum outside the very limited area in which it has been developed and prospected in the immediate vicinity of Gypsumville and Gypsum lake and in a correspondingly limited district 4 or 5 miles northeast of Gypsumville. The configuration of the land at Gypsumville where the gypsum forms low hills surrounded by a flat swampy country, is such that the deposits could not escape early discovery. It is most probable, however, that other deposits of gypsum occur at or near the surface along the general line of strike of the rocks underlying the Gypsumville district. The general strike and dip of the strata of this region bring the horizon of the gypsum to the surface along a belt of country probably 3 to 8 miles wide trending north and south with about the same general direction as the east shore of Lake Manitoba. The trend of the line of outcrop of this horizon if it extends as far south as the southern end of Lake Manitoba should take it between Shoal and Dennis lakes to the southeast. The heavy cover of drift and alluvium over the bed-rock in southern Manitoba makes any statement regarding the areal distribution of the Silurian strata in which the Gypsumville deposits lie in that part of the Province more or less hypothetical. If, as is probable, the general trend of the stiike remains the same as farther north, the Gypsumville horizon in southern Manitoba passes to the westward of Stonewall and Winnipeg, crossing the Red river below Morris, and the International line 40 or 50 miles southeast of Dominion city. The discovery during the summer of 1911 of a deposit of pure white gypsum 115 feet thick at a depth of 325 feet, 18 miles east of Dominion City, in the course of drilling, strongly supports this inferred eastern outcrop line of the Gypsumville deposits.

Northwest of Gypsumville, the gypsum horizon there developed may be expected to outcrop in a belt of territory lying a few miles to the eastward of Waterhen and Winnipegosis lakes which would probably cross the Saskatchewan river east of Cross lake.

Immediately east of the narrow belt outlined above lie rocks older than the gypsum; while to the west of it the gypsum, if present, is carried downward by the westerly dip to depths which make it unworkable.

It must not be inferred that workable deposits of gypsum will be found throughout the probable line of outcrop of the Gypsumville horizon outlined above. On the contrary, dolomites and shales and very impure gypsum will

undoubtedly be encountered more frequently than workable gypsum. It is probable, however, that conditions were favourable for the precipitation of beds of pure gypsum at various points in the Silurian sea which supplied the extensive bed of gypsum worked at Gypsumville. It is along the belt of outcrop of the deposits of this sea that we may expect to find other similar deposits.

The prospecting for gypsum which has been done about the south end of Lake Winnipegosis and in other districts to the westward of the area here considered, has been done in horizons of much later age which lie stratigraphically a few hundred feet higher than the beds at Gypsumville.

SAND AND GRAVEL

During the retreat of the waters of the post-Glacial lake known as Lake Agassiz, which at one time covered most of the prairie land of Manitoba, there were several periods in which the shore-lines remained stationary for considerable intervals. These periods of relative fixity of the ancient shore-lines are marked by a number of old beaches and bars which were built by the waves about the border of the old lake which, during its early stages, was many times larger than the combined size of all of the present lakes of Manitoba. These old shore-lines afford an inexhaustible supply of sand and gravel. In the vicinity of Ethelbert, the roadbed of the Canadian Northern has been built for a number of miles on the top of one of these old beaches. This beach near Ethelbert has a height in the middle of about 8 feet and a width of about 120 feet. Just south of Gypsumville station a cross section of another beach has been exposed by the construction of the railway which cut across it. These abundant, easily accessible and widely distributed beaches of gravel and sand will be of great value to the Province in furnishing material for good wagon roads at a moderate cost.

SALT

Any notice of the economic features of the geology of western Manitoba would be incomplete without reference to the salt which abounds in the Devonian rocks along the west side of Lake Winnipegosis. Innumerable salt springs which issue from the Devonian limestone along the western border of the lake attest the abundance of salt in these rocks. A small brook which enters Lake Winnipegosis north of Bell river has been estimated[1] to carry into the lake 37 tons of salt every 24 hours. Salt was manufactured in a small way for several years by one of the pioneers at Swan and Duck rivers and the Indians supplied themselves with salt by evaporating the saline spring waters long before the advent of the white man. At present, however, no use is made of the salt, and the salt industry remains a potentiality of the future. In some and probably most localities along the west side of Lake Winnipegosis, saline artesian water may be obtained by boring. A well at Barrows, on the south side of Red Deer lake, struck a strong flow of salt water at a depth of 410 feet. It may be found to be commercially profitable to manufacture salt from these saline waters in connexion with the operation of saw-mills in the timber lands west and north of Lake Winnipegosis. The heat necessary for the evaporation of the salt could be supplied from the combustion of the waste products of the mills at little or no cost. It might thus be possible to manufacture salt at a substantial profit as an adjunct to the saw-mill industry when it would be unprofitable as an independent industry.

It is not yet known whether the salt exists in a freely disseminated form in vesicular limestones or in beds of rock salt. The great quantity of salt indic-

[1] J. B. Tyrrell, Geol. Surv. of Can., Annual Report, vol. v for 1889–91 (1892), p. 179E.

ated by the numerous strong springs of brine distinctly favours the latter presumption, however. The probability of thick beds of rock salt in the Devonian formations is certainly strong enough to justify some exploratory drilling. In prospecting with the drill the mistake of drilling in the vicinity of salt springs should be avoided. Any beds of rock salt which may have existed near the belt of salt springs near the western border of Lake Winnipegosis must have been largely if not entirely dissolved and removed by spring waters. Salt beds, if present, will be found well to the westward of the saline springs. The region along the eastern base of the Porcupine and Duck Mountain escarpment presents the most favourable conditions for exploratory drilling for salt beds. In this area the salt horizon lies some hundreds of feet below the more or less impervious cover of Cretaceous shales and sandstones at a depth sufficient to protect it from the rapid waste of spring waters. This depth will probably nowhere exceed 1,500 or 1,800 feet below the bottoms of the larger stream valleys near the base of the mountain. The proximity of the Canadian Northern railway to this region affords excellent transportation facilities.

POTASH

The rapidly increasing and urgent demands in recent years for potash as a fertilizer of depleted soils, has directed attention to the extremely limited sources of supply which are known for this important fertilizing substance outside of the great potassium deposits at Stassfurt, Germany. During the last two years the United States Government has expended a considerable sum for exploratory drilling for this valuable mineral.

The possibility of finding in Manitoba a mineral resource of such value, in commercial quantities, appears to justify some reference in connexion with a discussion of the salt horizon. The chemical characteristics of the potash salts ally them closely to common salt and the most extensive deposits which are known occur in association with salt beds at Stassfurt, Germany. Because of the chemical and mineralogical resemblances between common salt and the salts of potash, the rocks or strata most likely to afford the latter are those in which the former occurs abundantly. That potash salts are associated with common salt in Manitoba is proven by each of twelve analyses of the saline waters of Manitoba made by this Survey[1]. One of these shows 209·39 grains of potassium chloride to the imperial gallon. The smallest percentage of potassium chloride shown by any one of the twelve analyses is 23·11 grains to the gallon. It is an interesting and significant fact that the great deposit of potash minerals at Stassfurt, Germany, is associated with rock salt and lies between thick beds of anhydrite and gypsum. This suggests careful examination of the gypsum and anhydrite and associated beds of the Gypsumville district as well as the beds which furnish the saline springs along the west side of Lake Winnipegosis. It is well to recall, in this connexion, that the Stassfurt bed which now furnishes most of the potash compounds of commerce was long known as 'Abrumsalze' or refuse salts, and considered worthless.

The financial results of the twenty-one German potash mines concerning which statistics are available should encourage systematic exploration for potash deposits in Manitoba. These twenty-one mines earned, in 1906, an average profit of 15·9 per cent on the invested capital, and declared an average dividend of 13·5 per cent. One of these shows a profit of 105 per cent[2].

[1] Geol. Surv. of Can., vol. v, 1889–91 (1892), p. 222E.
[2] U. S. Geol. Surv., Univ. Res. of N.S., part II, 1910 (1911), p. 757.

REGION EAST OF THE SOUTH END OF LAKE WINNIPEG

(*Elwood S. Moore*)

Introduction.

During the months of July and August, 1912, exploration work was carried on in the region east of the south end of Lake Winnipeg. The main object of this work was to verify reports concerning discoveries of gold and to report upon the economic future of the region. The area explored lies chiefly in Manitoba but partly in Ontario, and it is roughly bounded on the north by the Bloodvein river; on the east by the Red Lake district, which has been described by Dowling[1]; on the south by the English and Winnipeg rivers; and on the west by Lake Winnipeg.

The surveys made by the party are incorporated on the accompanying map, part of these being micrometer and the remainder track surveys. The micrometer surveys are as follow: Hole River lake; Wanipigow (Hole) river between the lake and the Rice Lake trail; the chain of lakes between Wanip'gow river and Manigotagan (Bad Throat) river; the Manigotagan, up the south branch to its head-waters and the connexion with the Oiseau (Bird) river; the Oiseau river and its chain of lakes from the north end of Eagle lake to Lac du Bonnet. The Wanip'gow river as far as Hole River lake and the Manigotagan as far as the western portion of Long lake had been previously mapped and the geology along these streams described by Mr. J. B. Tyrrell[2]. In this work the writer had the able assistance in the field, of Dr. R. C. Wallace, of the University of Manitoba, to whom is due the credit for almost all the topographic work. Acknowledgments are also due Mr. M. F. Sproule, of Winnipeg, Captain A. E. Pelletier, and several others, for valuable information furnished and other assistance rendered in promoting the field work.

Topography.

The topography of this region is similar to that of much of the Pre-Cambrian area of northeastern Canada. The highest hills, those on Eagle lake, do not rise more than 135 feet above the lakes at their bases, but the area is extremely rough and rugged. No definite measurement of the relief could be obtained, but measurements of the falls and rapids and an estimation of the drop in the intervening sections of the rivers placed the maximum altitude at 1,350 feet above sea-level.

The rivers of this area tend to follow fairly direct courses for long distances because the axes of their valleys are largely governed by the strike of the sedimentary rocks over which they flow. These streams all descend to Lake Winnipeg by numerous and often picturesque falls and rapids, the highest of the former being about 60 feet, and they flow in their lower stretches across the great silt and sand plains of glacial lake Agassiz. These plains are quite distinct along the streams up to an estimated elevation of 1,225 feet, but beyond that not much evidence of them was seen. On the Wanipigow river little sand-plain was observed beyond a point about 2 miles below the fork in the stream. Along the streams,

[1] Geol. Surv. of Can., part F, Annual Report, vol. VII, 1896.
[2] Geol. Surv. of Can., part G, Annual Report, vol. XI, 1900.

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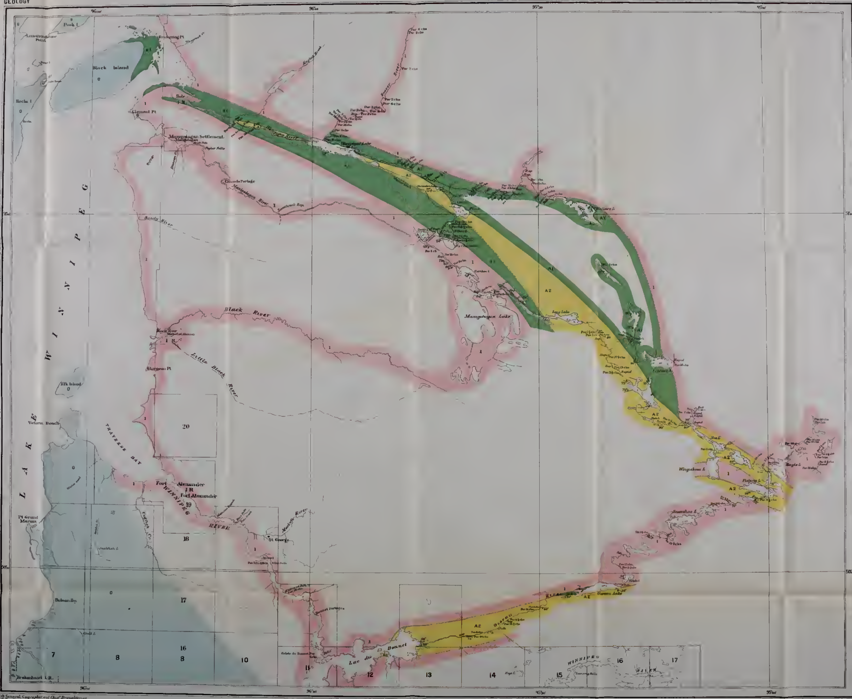
GEOLOGICAL SURVEY
R.W. BROCK DIRECTOR

GEOLOGY

ROUTE MAP



LEGEND

PALAEOZOIC — ORDOVICIAN — 0 — Sandstone and limestone

PRE-CAMBRIAN — 1 — Granite and gneiss

A2 — Wanipigow Series

KEEWATIN — A1 — Rice Lake Series

Symbols

Geological boundary

Geological boundary (position assumed)

45° Dip and strike

Vertical strata

Strike

Glacial striae

MAP 96A
(Issued 1913)

WANIPIGOW, MANIGOTAGAN AND OISEAU RIVERS

MANITOBA

Scale, $\frac{1}{253,440}$
Miles
Kilometres
4 MILES TO 1 INCH

GEOLOGY
E.S. MOORE, 1912
GEOLOGICAL MAP OF LAKE WINNIPEG

SURVEYS
J.B. TYRRELL, 1890 1891
R. WALLACE, 1912
DEPARTMENT OF THE INTERIOR

To accompany Summary Report by E.S. Moore, 1912

banks of clay, silt, and sand rise from 25 to 75 feet above the water, and so much sediment is carried down that the Wanipigow river has built up an exceptionally large delta where it enters Hole River lake and the cutting of the river banks causes great numbers of log jams along most of these streams, greatly impeding canoe navigation.

Agricultural Resources, Timber, and Game.

Along the lower stretches of the rivers entering Lake Winnipeg and the Winnipeg river, there are considerable areas of clay and silt plain consisting of soil suitable for agricultural purposes. On the Oiseau river from Lac du Bonnet to the first portage, a distance of about 4 miles, the land adjacent has been practically all settled by colonists from the shores of the Baltic sea. Even above this portage there are level stretches, but, on the whole, the upper portions of all these rivers are comparatively rough and rocky.

The timber, as a rule, is small, and great areas have been devastated by fire. On the Beaver river above the second portage there is some ash, and some jackpine 30 inches in diameter, as well as considerable tamarack swamp occurring at intervals. On the same stream between the sixteenth and seventeenth portage there is some fine spruce and poplar, but great areas along the upper portion of this stream have been burned off. On Wanipigow river above the falls some spruce runs 24 to 30 inches in diameter and there is considerable small ash and elm. For some distance above the Rice Lake trail there is good timber, but around the upper lakes on this river the timber is small or has been wiped out by fire.

Near Muskrat lake on the Manigotagan river, there is some timber of value, but on the upper waters of the Manigotagan and the Oiseau rivers the timber is usually small or it has been recently destroyed.

Descending the Oiseau, below Snowshoe lake, there is some fairly good spruce, jackpine, and poplar.

There is an abundance of game in the region, including the red deer, caribou, moose, and bear. Ducks in great numbers subsist upon wild rice which is abundant along the streams and silted lakes.

General Geology.

The geological formations of this region are tentatively arranged in the following classification:—

Quaternary	Pleistocene	Glacial drift and lake deposits.
Pre-Cambrian	Post-Lower Huronian?	Manigotagan granite, pegmatite, and gneiss.
	Huronian?	Wanipigow series; conglomerate, arkose, greywacke, chert, jasper, grey gneiss, and schist.
	Keewatin	Rice Lake series; greenstone, quartz porphyry, rhyolite, trachyte felsite, green and grey schist.

As indicated in the classification, there is some uncertainty as to whether the sediments should be classed as Huronian. Owing to the fact that in the Timiskaming region in Ontario, extensive deposits of sediment occur in the Keewatin and that a great amount of detailed work would be necessary for the accurate correlation of the sediments of the region east of Lake Winnipeg, it seems advisable to designate some of the formations and series in this region by local names. It is the writer's opinion that the Wanipigow series might safely be considered of Huronian age since the conglomerate indicates an extensive unconformity

and has many of the physical characters of Huronion conglomerates, but until further work is done, the series will be known under the names of the two prominent rivers in this region along which they are well developed. The Wanipigow series and Keewatin, Rice Lake series, have been separated chiefly on the basis that the Keewatin contains the bulk of the igneous rocks and also that pebbles of most of the Keewatin rocks may be found in the Wanipigow conglomerate. Some of the granite may be Laurentian, but it was found intruding the conglomerate in so many widely separated areas that most of it must be regarded as younger than the Wanipigow series and, therefore, post-Lower Huronian if this series should be of Huronian age. It is greatly cut up by dykes and irregular masses of pegmatite.

Keewatin, Rice Lake Series.

As indicated on the accompanying map, the Rice Lake rocks extend from Lake Winnipeg eastward up Wanipigow river. They are divided into two bands by a syncline of the Wanipigow series so that they lie to the north and south of Rice lake, the southern band narrowing and the northern widening so as to enclose the Wallace Lake area and the area lying between it and the south branch of the Manigotagan river. Another small area is found along the northwest shore of Oiseau lake.

Much of the Rice Lake series is made up of acid igneous rock, including quartz-porphyry, rhyolite, and orthoclase-porphyry. There is a great deal of felsitic rock, the texture of which in many cases is due to silicification and other changes produced by the granite intrusion. There is little doubt that some of these rocks may be altered Wanipigow sediments, but it is impossible to differentiate them in the field.

Proportionally, the amount of ellipsoidal greenstone in this region is less than in many other Keewatin areas. The area of Rice Lake rocks on Ouiseau lake consists chiefly of altered diabase and this rock is a fairly common type in other parts of the region. Pebbles of all these rocks occur in the Wanipigow conglomerate.

The Rice Lake rocks contain more of the large quartz veins than the Wanipigow, probably for two reasons, viz, the Rice Lake suffered extensive diastrophism before the Wanipigow formations were laid down and were, therefore, more fractured; and the Rice Lake being buried deeper than the Wanipigow at the time of the granite intrusion, was more highly silicified.

Wanipigow Series.

The Wanipigow series is very prominent in this region. The rocks occur as a narrow, closely folded, synclinal band on Wanipigow river and gradually widen, covering a broad area on the upper waters of the Manigotagan until cut off by the later granite. A long band extends down the Oiseau river and to a large extent controls its course.

The most important rock of this series is a conglomerate which was traced from the fourth portage on Wanipigow river, eastward across Oiseau river, a distance of approximately 70 miles in a straight line. Throughout this distance there are patches of the formations which are crowded with pebbles, while these are lacking in others and the rock grades into an arkose or greywacke. Associated with the conglomerate are beds of arkose and also bands of schist and slate resulting from altered arkose and greywacke. The matrix of the conglomerate is similar to these latter rocks although occasionally approaching a sandstone in composition. Well rounded pebbles of the following rocks were found: quartz, up to 3 inches in diameter; rhyolite, granite up to 1 foot in diameter; felsite, greenstone, jasper, and chert.

Near the contact with the granite the conglomerate often becomes unrecognizable, while at other times it becomes porphyritic in appearance. At the south end of Eagle Rock lake, a glaucophane schist has been developed and at the west end of Bird lake, a garnetiferous schist. The finest exposures of conglomerate are found on Bee lake and the lakes between it and Oiseau river. Another very widely distributed rock is a mica schist or gneiss which consists largely of quartz and biotite, is grey to pepper-and-salt in appearance, and has probably originated in most cases from a sediment since it can be traced into a less altered phase of greywacke, arkose, or conglomerate, but in thin sections some of it appears to be igneous. It answers very well the description given by Lawson for parts of the Coutchiching formation. This formation is extensively intruded by the granite, over large areas.

A narrow band of iron-formation consisting of chert and jasper, interbanded with greywacke and schist, occurs on the first lake on the South Branch of Manigotagan river. The relations of this iron-formation to the conglomerate seem to place it in the Wanipigow in spite of the fact that pebbles of chert and jasper occur in the Wanipigow conglomerate. This iron-formation is mentioned again in the section on Economic Geology.

Manigotagan Granites, Gneisses, and Pegmatites

The granite and gneisses are the most widely distributed of all the rocks in the region and massive granite is the most characteristic phase. The pegmatites are extensively developed, especially along the northern contact, in the vicinity of Turtle, Clearwater, and Caribou lakes and along the Oiseau River system. The granite is largely a hornblende type varying from fine to coarse grained and porphyritic. It is grey to reddish in colour and the red variety often forms a very attractive stone. A rather fine-grained, reddish type is remarkable for a horizontal jointage which causes it to split off in thin slabs from 1 inch to 6 or 8 inches thick and to resemble strongly a sedimentary rock. This type is prominent on Turtle, Clearwater, Caribou, and Eagle Rock lakes.

There are patches of gneiss the age of which is in doubt because the rock appears older than the massive granite and is cut by granite dykes. It was found, however, that these granite dykes as a rule graded into pegmatite dykes which also cut the massive phase. There is also a difficulty in explaining the presence of so many granite pebbles in the Wanipigow conglomerate which is cut by the granite. Possibly some pre-Wanipigow granite is still in existence though not recognized as such, unless we assume a complete re-solution of the old granite. Some of the gneiss bears a resemblance to the Laurentian of the east, but owing to the fact that it cuts the conglomerate over such wide areas it must be nearly all regarded as post-Wanipigow and, therefore, in the writer's opinion, at least post-Lower Huronian.

The pegmatites grade from coarse to fine in grain and from red to grey in colour. The two colours were frequently found grading from one to the other in the same dyke or mass, and, therefore, do not indicate different ages as suggested by Tyrrell.[1] Orthoclase crystals up to 4 inches in diameter were seen on Oiseau river.

The granites and pegmatites are believed to be the source of the quartz veins and the gold ore of this region, since the veins are rather closely associated with the contact zone, and the older rocks of this zone are highly silicified by the granite intrusion.

[1]Loc. cit.

Economic Geology.

The region under discussion has attracted attention because of the discovery of iron and gold. For a good many years iron has been known to exist on Black island, in Lake Winnipeg, and some gold prospects have been exploited along the shore of the lake in the vicinity of Wanipigow and Manigotagan rivers, but the latter have been practically all abandoned. In March, 1911, Captain A. E. Pelletier discovered the claim on Rice lake, known as the Gabrielle, and the areas which have since attracted attention are those adjacent to Rice lake and Wanipigow river to the north of this lake, one on Long lake and one on the small lake north of Eagle Rock lake, shown on the map at the head of the northwest branch of the Oiseau river.

Iron-formation was seen on the first lake on the south branch of the Manigotagan river above the forks, and again on the lake lying between Bee lake and Eagle lake. A small amount was also seen on the northeast shore of Wallace lake.

A band of rusty schist, or fahlband, carrying a good deal of pyrite, extends intermittently along the lower portion of Oiseau river from about 2 miles above Lac du Bonnet to the fourth portage, a distance of about 10 miles. So far as observed, this band is not of importance as it did not grade into typical iron-formation.

In an outcrop on the bank of the river near the southern end of the band there is a mass of pyrite, quartz, and sufficient pyrrhotite to affect the compass perceptibly. This outcrop has weathered to a dark brown and reddish gossan. The enclosing rock is a biotite schist and apparently of sedimentary origin.

Quartz Veins in the Vicinity of Rice Lake

The only claim in the region upon which any development work worth mentioning has been done, is the Gabrielle, the first claim discovered. This property is located on the northwest shore of the lake, and a shaft 22 feet deep, timbered for 10 feet, has been sunk by Captain Pelletier. The shaft lies 65 feet from the shore and is sunk on an irregular quartz vein cutting a fine-grained, schistose greenstone which Professor Wallace had previously found, by examining a thin section, to consist almost entirely of hornblende and quartz, the latter appearing to be introduced as a secondary constituent in the rock. The rock is undoubtedly a highly altered diabase. The strike of the foliation in the schist is S. 80° E. and dip 50° N. 10° E. The lode is made up of numerous stringers in a brecciated zone filled with quartz, and the strike of the lode is approximately north and south. It has been stripped for 65 feet along its length and over a width of 10 feet. The quartz impregnates the country rock to a considerable extent and it is well mineralized with pyrite. The country rock is also well mineralized with pyrite in cubes, or oxidized so as to produce a reddish and jaspery quartz. There is also some siderite or ankerite in the vein.

The mass of quartz is quite large, but its extreme irregularity makes its future quite uncertain, and it would have been more profitable to strip the vein a little more than to sink a shaft. Free gold is well distributed throughout the lode and no difficulty is experienced in finding good specimens. A one-stamp mill was being installed at the time of our inspection.

On a small point in the lake a few yards northwest of the shaft described above, there is another vein on the same claim. It is a very irregular lode and breaks up into stringers following the strike of the schist, which consists of an altered acid rock mixed with a little greenstone. This vein, where exposed, is unimportant but it might join the vein described above, under the drift north

of the shaft. Lying northwest of the shaft and 600 paces from the lake is another vein on the Gabrielle property. A little stripping has been done on this vein and where it runs under the swamp at the northern end it is 6 feet wide. It widens out to the south to between 12 feet and 15 feet, with numerous stringers extending over a width of 25 feet. It has not been stripped for more than a few yards, but at the south end it becomes dissipated in the country rock by breaking up into stringers and pinching out. The writer did not see any visible gold, but the quartz looks favourable and is fairly well mineralized with pyrite and siderite or ankerite. The strike of the vein is N. 65° W. and cuts across the strike of the schist which lies S. 80° E. The country rock is a schistose, feldspar-porphyry. This vein seems to lie along the same line of disturbance as a vein which occurs on an island near the north shore of Rice lake and southeast of the former vein. Cutting part way across this island there are two veins, one near the east end runs northwest by southeast across the schists which strike east and west. It varies in width from 3 feet to a group of stringers making a lode 6 feet wide, then pinches and comes in again as a respectable vein at the water's edge. The country rock is a schist derived from a rock of the composition of latite. It is well mineralized with cubes of pyrite and carries a little gold.

At the western end of this island there is a large mass of quartz striking almost north and south and possibly connecting under the drift to the north with the one just described. In the widest place it is 15 feet, but it fingers out into the country rock and has no clear-cut borders. It has only been stripped for a short distance, but it is well mineralized with cubes of pyrite and some siderite. No visible gold was found.

Another vein occurs on a point in the northeast corner of Rice lake and a mass of quartz may be seen under the water near the shore.

The veins described above are the more important ones found in the region, but there are many others of smaller size or apparently quite barren, scattered throughout this area. There are some around Horseshoe lake, some north of Wanipigow river, and some on Elbow lake where a large mass crosses the lake at the narrows, near the north end. On Wallace lake, near the northwest corner, there is a mass of white, barren quartz about 30 feet in diameter lying near the granite contact.

Quartz on Long Lake

The largest masses of quartz in the region were seen on Long lake, an expansion of the Manigotagan river. Besides a number of small veins, two large ones were examined. One of these lies on a point on the south shore and less than a mile from the west end of the lake. It is roughly 140 feet in diameter and is more of the nature of a segregated mass than a vein. It grades by stringers into the country rock which is an acid, felsitic type apparently of igneous origin. The quartz is nearly white and very barren in appearance.

A more attractive-looking mass of quartz has been discovered by A. Anderson on the north side of the lake and 600 paces from the shore. This mass was traced for 1,120 feet and it has a maximum width of 78 feet. It runs S. 70° E,. while the strike of the country rock is northwest by southeast. It is situated near the contact between the granite and Rice Lake schist, in a feldspar and granite-prophyry which appears to be a contact phase of the granite. At the eastern end the vein runs out entirely, and towards the west it becomes pretty well broken up into stringers before disappearing under the swamp. The country rock and quartz finger out into one another and the porphyry shows fine examples of torsion cracks filled with small quartz veins. A portion of this vein contains a grey chert which often presents a brecciated appearance. Associated with this chert in some places there is pyrite, chalcopyrite, and a little bornite. The vein, as

a whole, was not sampled but an analysis made by Mr. N. L. Turner of one of the best specimens collected, showed:—

Copper	1·15 per cent.
Gold	None.
Silver	None.

This result was disappointing as the size of the body of the quartz and the well mineralized nature of a portion of it had appeared quite promising.

Quartz on the Lake North of Eagle Rock Lake

On the northeast side of the sixth small lake north of Eagle Rock lake on Oiseau river, there is a large mass of quartz in hornblende granite. The granite is massive and the quartz and country rock grade into one another by countless stringers and tongues so that the body of quartz has no sharp walls. The granite has been altered to some extent so that it carries chlorite, muscovite, and what appears, in the hand specimen, to be a little serpentine. The quartz is apparently an end product deposited from the magma. A few small dykes of felsite and pegmatitic granite occur in the vicinity but they are not closely associated with the quartz.

This body of quartz has a maximum width of 200 feet and it was traced for approximately 3,900 feet along a line N. 10° W. Towards the ends it narrowed and was lost in the country rock. The quartz is white and pinkish to watery in appearance and very little mineralized. On the whole it presents a barren appearance.

Iron-Formation

Along the south side of the first lake expansion on the south branch of Manigotagan river, above Long lake, there is a mass of chert. What appears to be a continuation of this occurs as a narrow band of jasper cutting across the centre of the lake directly east of Bee lake, as shown on the map. On the creek connecting the above-mentioned lakes there is a strong local magnetic disturbance due to iron-formation in the Wanipigow series.

On the first lake mentioned above, the chert is massive, almost black in colour along the north side, and grades to grey on the south. It has a maximum width of about 300 feet and runs out into small bands in the schist and greywacke. It is associated with a complex mixture of rock, consisting of bands of greywacke, igneous rock, and green to brownish schists, some of the latter resembling tuff. Both the chert and surrounding rocks contain considerable pyrite, and small quartz veins cut the chert and also carry pyrite. While some of this pyrite occurs in cracks in the chert and is thus later in time of formation, some of it nevertheless seems to be syngenetic with the chert. On the second lake there is some siliceous, slaty schist containing a little iron which greatly disturbs the compass. These rocks grade into true red jasper which is interbedded with arkose and greywacke, apparently of the Wanipigow series, since they are interbanded with the conglomerate. Some of the jasper is sufficiently concentrated to make a low grade hematite ore, but the quantity is very limited and the three bands of jasper are each only a foot or two wide. The rocks at this point are locally folded into a most intricate structure, but the general dip is about 50° S. No evidence of this iron-formation was seen on the Oiseau River system to the east.

A narrow band of ferruginous and siliceous schist occurs along the northeast shore of Wallace lake, but it is not regarded as important.

Economic Possibilities of this Region.

There have been many useless claims staked in this region and only a few merit any attention. The veins show a marked tendency to irregularity like those in other Pre-Cambrian regions, but some of them are of exceptional size and a few are well mineralized. The proper procedure in prospecting will be to strip a good deal before spending much on sinking shafts.

It will no doubt be found that considerable secondary enrichment has occurred in some of these veins, i. e., that the percentage of free gold will be considerably higher in the upper than in the lower levels.

As the better veins seem to be rather closely associated with the granite-Rice Lake contact and genetically connected with the granite, the best areas for prospecting will be found in the Rice Lake rocks shown on the map and not too far from the granite. The northern portion of the Rice Lake area is probably the most promising. The writer considers the area well worth a prospector's careful search although, so far, no deposit of special importance has been discovered.

Petrographic Notes on the Metamorphic Rocks.

The changes produced in the rocks of this region by dynamo-regional metamorphism are of the ordinary type, and have resulted in the production of the common types of schists and gneisses. The contact effects of the granite intrusion are, however, more interesting.

One of the most far reaching effects of the granite intrusion is the production along the contact of a felsitic and highly siliceous rock, the origin of which often cannot be recognized in the field since these rocks grade into sediments in some cases and into fine-grained igneous rocks in others. On the north shore of Red Rice lake, a rock occurs which resembles some of the altered sediments, but in thin section it is seen to be an altered trachyte consisting of orthoclase, actinolite, muscovite, and finely divided chlorite which gives the surface a greenish tinge. The feldspar phenocrysts are in some cases decomposed.

At the south end of Eagle Rock lake, on Oiseau river, several specimens were collected at the contact to illustrate the effects of the granite on the Wanipigow conglomerate and arkose. The first specimen was of slightly gneissic granite and was obtained 200 yards north of the contact. The second was taken close to the contact and consists of a fine-grained, pink gneiss, and, in this section, the minerals found were orthoclase, albite, quartz, biotite, muscovite, and pyrite, the latter almost always coated with limonite. The mica flakes are arranged in lines, indicating a gneissic structure and the quartz and feldspar show some recrystallization. Another sample taken at the contact, in the hand specimen might be taken for either an igneous or sedimentary rock. In thin section it proved to be granite and to carry some magnetite as an accessory mineral. The rock is, to a large extent, recrystallized. The last specimen examined was taken close to the contact and was a grey, fine-grained schist with small lath-shaped crystals nearly black to bluish in colour. Under the microscope it was found to be a metamorphosed sediment and to contain quartz, feldspar, and a good deal of glaucophane. Some biotite, one speck of titanite, a little pyrite and magnetite also occurred. The groundmass was largely recrystallized. The mineral identified as glaucophane occurs as prisms and grains and often forms branching and fingering crystals running out into the surrounding minerals and showing the secondary origin of the mineral. It is strongly pleochroic with brownish blue and other shades of blue, to yellowish green. The extinction angle is in almost all cases 6° but in one crystal as high as 11°, the upper limit reported for

glaucophane. The pleochroism is on the whole more like that commonly found in riebeckite, but the elongation of this mineral is distinctly positive and its other optical properties are more like those of glaucophane than of any other mineral.

In the conglomerate it was found that there is a tendency to produce a porphyritic appearance in some cases by the development of feldspar crystals through recrystallization.

As previously mentioned in this report, there are large areas of a speckled or pepper-and-salt like gneiss, the origin of which is sometimes in doubt, although it can often be traced into a sedimentary rock. A specimen of this rock taken on Fishing lake, Oiseau river, was examined and the megascopic characters showed a grey, fine-grained, speckled rock consisting chiefly of quartz. In thin sections it was seen that the rock is composed of about one-fifth biotite, three-tenths quartz, and one-half feldspar. Specks, grains, and irregular pieces of pyrite occur. The feldspar is largely albite or oligoclase and the rock appears to be a metamorphosed greywacke or arkose. It strongly resembles a phase of the Coutchiching formation as described by Dr. Lawson. It is greatly cut up by dykes of granite and pegmatite. Another type of gneiss which somewhat resembles this one but which is slightly less granular and is lighter in colour, proved to be an altered granite when viewed under the microscope.

Another phase of contact-metamorphism was studied on Wanipigow river, a short distance below the fork in the stream. At this point the granite had intruded the Wanipigow rocks and a gradation from the acid to a more basic phase of the granite was observed. A porphyritic texture has also been developed in a sediment so that it resembles an altered quartz-porphyry, with blue, opalescent phenocrysts. In thin section the rock appeared to be either a mass of vein quartz or a fine-grained sandstone which had been completely recrystallized from a finely granular condition, and which had larger grains developed by metamorphism among the smaller ones. The large grains in the sections are distinctly blue and opalescent to the naked eye, but under the microscope, of the ordinary grey type. It is supposed that the blue colour is due to numerous inclusions in the quartz less than one-half a wave length of light in thickness, and in similar blue quartz grains, collected in the vicinity of the Tip Top copper mine, Ontario, many more inclusions were seen than in the smaller grains of colourless quartz in the same section. In the sections from the Wanipigow River area only indistinct traces of inclusions could be seen with the high-power microscope. It has been observed that these blue, opalescent, quartz grains are characteristic of the granite contact zone in many parts of the Pre-Cambrian area of the north, and the writer believes that the crystalline character of the grains and their rounded or xenomorphic form bear some close relation to the temperature and rate of deposition and to the fact that they develop in rocks already consolidated.

In these quartzose rocks described above there is some zoisite, epidote, and chlorite.

Other sections examined showed, in one case, the alteration of a dacite and the injection of quartz as a secondary mineral, and in another, a rock of the composition of diorite apparently produced by the assimilation of more basic rocks by the granite, at the time of intrusion.

The item of chief economic interest connected with the contact activities of the granite is believed to be the supplying of quartz directly to the quartz veins in the vicinity of the granite by the granitic magma and the gathering together in the veins, by hot solutions, of a certain amount of quartz distributed throughout the adjacent rocks.

NOTES CONCERNING THE FEATURES OF ST. JOSEPH ISLAND, LAKE HURON, ONTARIO [1].

(Frank Leverett)

At the time of the greatest expansion of lake waters, following the melting of the great ice sheet, in what is termed the Algonquin Lake stage, the islands at the north side of Lake Huron were reduced to a few scattered islets, of which the largest was on St. Joseph island, and now known as 'The Mountain'. It had an area of about 8 square miles. The other islands having points which stood above the highest lake stage had a combined area of perhaps not more than 1 square mile. Two of them are located in the east part of Manitoulin island, one on Cockburn island, and one on Mackinac island. The north shore of this expanded lake was only a few miles inland from the North channel. The eastern part of the northern peninsula of Michigan, as far west as the meridian of Munising, and wide areas in the northern part of the southern peninsula, were submerged at this time and presented a few widely scattered islands.

The beach marking the highest levels of the waters is not at a uniform altitude, as at the time it was formed, but shows a marked rise to the north due to the elevation of the country north of the Great Lakes. This altitude at the south end of Lake Huron is 605 feet above sea-level, while on the upland north of Sault Ste. Marie it is 1,015 feet. On St. Joseph island it is 930 to 934 feet, and on Mackinac island, 812 feet.

As shown in the notes accompanying the line of levels run from Hilton to 'The Mountain' there were numerous shore-lines developed as the waters lowered from the highest Algonquin level to the present water level. No attempt was made to trace the course of these shores around the island, as was done in the case of the highest Algonquin beach. The complete tracing of all these shore-lines would require several weeks' work.

There are two independent causes for the lowering of the water level. One cause of lowering which applies to several of the higher and earlier beaches, is found in the differential uplift referred to above. Inasmuch as the lake had its outlet to the south, the northward differential uplift caused the water to recede from this part of the shore. The lower beaches which were formed converged southward and finally became united in a single beach. Another cause of lowering is found in the opening of a different outlet at a lower level than the one in operation. Thus the shifting of outlet from the St. Clair river to an outlet past North Bay to Mattawa river instituted the Lake Nipissing stage and the name Lake Algonquin is then dropped. The Battlefield and Fort Brady beaches, which stand immediately above the Nipissing, were close to the transition, and possibly during the development of some of the lower of these strands water discharged eastward. The Ottawa outlet seems to have been at that time only partially blocked by the ice sheet, while during the highest stages of Lake Algonquin it was completely blocked.

The portion of St. Joseph island above the level of the highest beach has morainic topography, the surface being diversified by swells and sags and a few sharp knolls, of which Salters hill is the most conspicuous. Much of the surface

[1] The work herewith reported on by Mr. Leverett was performed in co-operation with the U.S. Geological Survey.

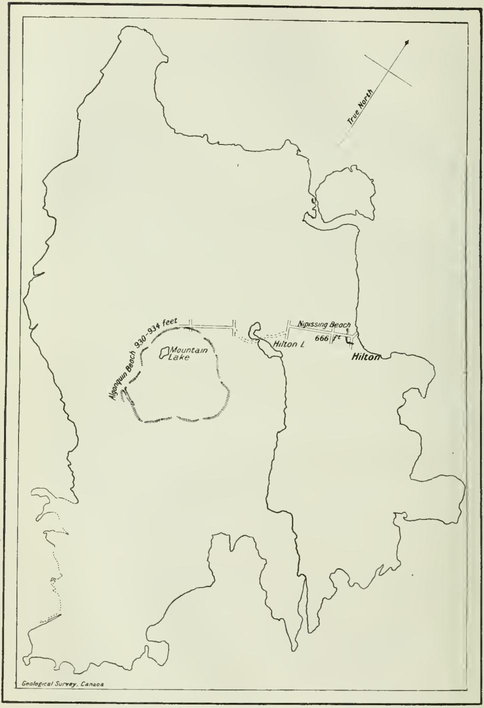


Fig. 7.—Index showing Algonquin Beach on St. Joseph island, Lake Huron.

is thickly strewn with boulders and the drift deposits are full of rather coarse stones. Aside from the obstruction to cultivation presented by the boulders, this is a very productive agricultural district. Orchards and various small fruits are grown with great success. Because of its relief above the surrounding districts, as well as because of its insular situation it is protected from late spring and early autumn frosts.

Several of the earlier Algonquin beaches are formed largely of coarse material from the drift and are consequently rather barren as well as difficult of cultivation. This condition does not affect the lower beaches to so marked a degree, there being a larger admixture of sandy material with the clay. Throughout the island the prevailing type of soil is a sandy loam, the gravelly and cobbly strips being chiefly in connexion with the higher Algonquin beaches.

Much of the island is still covered with luxuriant hardwood forests, the farming settlements being confined chiefly to the morainic tracts above the highest Algonquin beach and the vicinity of the villages of Hilton and Richards landing.

LEVELS on St. Joseph island, Ontario, from Hilton along Hilton Road to "The Mountain."

Party: Frank Leverett, Lloyd G. Hornby.
Date: June 24, 1912.

Ft. Rod +	Ft. A.T. H I	Ft. Rod —	Ft. A.T. T P	Ft. Rod Side shots	Ft. A.T. B. M.	Remarks
Ft.	Ft. A.T.	Ft.	Ft. A.T.	Ft.	Ft. A.T.	
12·76	594·76	0·93	593·83	....	582·00	Bench mark, water level St. Mary river.
12·47	606·30	0·71	605·59	2·95	603·35	Faint beach.
13·40	618·99	0·12	618·87	0·40	618·59	Road intersection.
13·40	632·27	0·31	631·96			
11·33	643·29	0·26	643·03			
8·81	651·84	0·32	651·52	7·26	644·58	Low-water level, Nipissing beach.
				2·50	649·34	Base of steep cut bluff (Nipissing storm beach).
12·32	663·84	0·39	663·45	9·60	665·95	Top of Nipissing bluff.
12·10	675·55	0·00	675·55			
13·60	689·15	1·87	687·28			
11·86	699·14	0·14	699·00	3·10	696·04	Top of sandy ridge by Church of England cemetery.
10·77	709·77	0·29	709·48			
11·52	721·00	0·55	720·45	6·2	714·80	Base of Ft. Brady beach opposite Fremlin's house.
13·09	733·54	0·34	733·20	6·48	727·06	Top of Ft. Brady beach opposite stone house.
11·50	744·70	0·48	744·22			
12·80	757·02	0·16	756·86	4·00	753·02	Crossing of base line with road. Base of Battlefield beach.
10·83	767·69	0·30	767·39			
11·81	779·20	1·60	777·60			
5·74	783·34	9·05	774·29	1·64	781·70	Top of a Battlefield beach in front of a cemetery gate. Gravel pit nearby by roadside has same altitude at top.
4·75	779·04	2·88	776·16	1·4	780·44	Cobbly Battlefield bar ½ mile from base line.
8·86	785·02	0·36	784·66	3·0	782·02	Base of bank at next higher beach.
10·98	795·64	0·44	795·20			
9·47	804·67	1·47	803·20	7·06	797·61	Top of Battlefield beach (facing west).
1·75	798·03	12·00	786·03	....	786·03	Battlefield beach at R. Bishop's house.

Ft. Rod +	Ft. A.T. H I	Ft. Rod —	Ft. A.T. T P	Ft. Rod Side shots	Ft. A.T. B. M.	Remarks
4·04	790·07	0·56	789·51	5·4	784·67	Battlefield beach at road by R. Bishop's house.
10·28	799·79	2·40	797·39			
1·85	799·24	10·25	788·99			
4·10	793·09	5·90	787·19	7·8	785·29	Battlefield beach near road intersection.
1·66	788·85	9·66	779·19	....	779·19	Road intersection at northwest road.
1·10	780·29	12·40	767·89			
1·14	769·03	12·97	756·06	....	756·06	Lower Battlefield beach.
0·85	756·91	12·06	744·85			
1·13	745·98	1·80	744·18			
12·50	756·68	0·80	755·88			
10·24	766·12	0·02	766·10			
13·60	779·70	0·07	779·63			
3·53	783·16	12·16	771·00			
0·35	771·35	8·41	762·94			
3·23	766·17	12·81	753·36			
0·68	754·04	12·55	741·49	1·0	753·04	Cut bank north of Hilton lake
1·23	742·72	12·73	729·99			
0·00	729·99	9·20	720·79	9·4	720·59	Surface of Hilton lake.
7·00	727·79	4·25	723·54			
12·64	736·18	0·33	735·85	....	736	Level of plain south of Lake Hilton.
13·35	749·20	1·69	747·51			
11·96	759·47	0·55	758·92			
9·70	768·62	1·07	767·55			
10·48	778·03	0·29	777·74	....	777·74	Beach.
11·86	789·60	0·70	788·90			
12·43	801·33	1·12	800·21			
11·45	811·66	0·15	811·51			
6·05	817·56	1·00	816·56	3·5	814·06	Road intersection with M. and L. line Low sandy gravel beach.
12·80	829·35	1·71	827·64	0·10	829·25	Sandy Algonquin bar.
13·40	841·04	0·05	840·99			
14·65	855·64	1·00	854·64	6·81	848·83	Algonquin gravel bar.
6·00	860·64	0·30	860·34	3·70	856·94	Base of prominent cut bluff.
11·94	872·28	0·23	872·05			
11·25	883·30	0·13	883·17	....	886	Line of lots 12 and 13.
11·45	894·62	0·75	893·87			
10·96	904·83	1·12	903·71	5·7	899·13	Beach at brow of bluff in lot 12.
10·82	914	0·53	914·00	3·0	911·53	Top of Algonquin bar in lot 12.
....	....	....	....	9·8	904·73	Base of same bar near middle of lot 12.
10·34	924·34	1·03	923·31	6·75	917·59	Top of Algonquin bar near middle of lot 12.
8·01	931·32	1·80	929·52	5·00	929·32	Bar middle of lot 11.
....	....	....	....	....	929·52	Bar at 10 line.
....	....	....	....	18·2	913·12	Intersection 10 line road with Hilton road.
....	....	....	....	2·0	929·32	Algonquin bar beyond road intersection.
....	....	....	....	1·6	929·72	Algonquin bar on 10 line road.
13·00	942·52	....	....	2·3	940·22	Top of cut bank of highest Algonquin west of 10 line road.
....	....	....	....	11·66	930·86	Highest Algonquin, low-water stage.
		On Hilton Road west from 10 Line road.				
....	....	....	929·32			
3·24	932·56	....	....	2·0	934·56	Storm beach of highest Algonquin in cultivated field in lot 10, about 100 yards from Hilton road.

THE SILURIAN OF MANITOULIN ISLAND AND WESTERN ONTARIO

(*M. Y. Williams.*)

Scope of Work and Acknowledgments.

The field season of 1912 was principally occupied with a study of the Silurian stratigraphy of the eastern part of Manitoulin island and the correlation of the Manitoulin formations with those of the mainland. Fossils were collected from many horizons and from a number of localities. Several sections were carefully measured by means of a hand level, these measurements being supplemented by numerous aneroid measurements which were corrected from readings of a stationary barograph. More than 50 miles of formation boundaries in the vicinity of Manitowaning were resurveyed by pace and compass methods.

Between July 23 and August 15, Professor Charles Schuchert, of Yale University, spent thirteen days with the writer, studying the Ordovician-Silurian sections of Georgian bay and Manitoulin island. Professors W. A. Parks and W. H. Walker, of the University of Toronto, and Dr. A. F. Foerste of Dayton, Ohio, joined Professor Schuchert and the writer on August 8, and the succeeding five days were devoted to a study of the Ordovician and Silurian of the eastern part of Manitoulin island.

The writer is indebted to the above-mentioned gentlemen for assistance and advice in the field, and special acknowledgments are due Professor Schuchert for his assistance in determining the age and correlation of the lower formation of the Silurian of the Georgian Bay region, formerly called 'Clinton.'

Thanks are also due the Benedum-Trees Oil Company, of Pittsburgh, Pa., for well records furnished by them, which have greatly assisted in determining the thickness of the Cincinnati group.

Field work in the Silurian regions lasted from June 6 to October 18, with the exception of about two and one-half weeks which were spent on the Devonian formations of Thedford, Ontario.

Location and Area.

The Silurian regions studied lie along the shores of Georgian bay from Collingwood west and north through Bruce peninsula, and as far west on Manitoulin island as Providence and Gore bays. Collingwood mountain, Craigleith, Thornbury, Meaford, Wiarton, Lion head, Cabot head, and Fitzwilliam island were all visited, but the most detailed work was done on that part of Manitoulin island east of Lake Manitou and Providence bay. Two days were spent at Niagara Falls at the close of the field season.

Previous Work.

The first published description of the geology of the Manitoulin islands is that by Alexander Murray[1]. His account contains a concise description of the physiography and geology of the shores and islands of Lake Huron, and formed

[1] Geol. Surv. of Can., Report of Progress for 1847–8.

the basis for later reports. Sir William Logan[1] makes frequent reference to the Manitoulin Island region in his descriptions of the various formations of Canada, and his map of Canada shows the formation boundaries. Robert Bell[2] visited the Manitoulins in 1865 and his reports based upon the work commenced in that year and continued, at intervals, until 1896, form the latest comprehensive accounts of the region.

Topography.

Manitoulin is the largest of the group of islands which extend from the Bruce peninsula north and west in crescentric shape, separating Georgian bay and the North channel from Lake Huron. It exhibits perhaps best of all, the land forms characteristic of the group. From north to south, the topography assumes the character of a gently-rising stair. Four comparatively even land surfaces occur, each dipping southward below the succeeding surface, with the exception of the last which dips rather evenly below Lake Huron. Corresponding to risers in a stair, steep escarpments mark the ascent of each surface to the succeeding higher one. The escarpment-fronts are very sinuous, with the result that the lengths of the northern land contours are many times that of the island. The resulting contrast between the irregularity and deep embayments of the northern shore and the comparative straightness and regularity of the southern shore is very striking. The term 'Cuesta' may be most aptly applied to the asymmetric steps of the stair.

Much of the sinuosity of the escarpment fronts is evidently due to glacial abrasion and plucking. Striæ, boulders, mounds and ridges of tillite and remarkable rock furrows all attest to the activity of the ice. The glacial action appears to have been concentrated along axes about 5 or 6 miles apart which may have been located to some extent by the presence of low anticlines, as already described by Bell.[3] Apart from this, the ice tended to plough the massive Silurian dolomite into furrows 15 to 20 feet wide and 3 to 5 feet deep. The finest examples of these glacial furrows are to be seen at South Baymouth where the ice moved about W. 42° S.

The physiographic contrast between Manitoulin and the accompanying islands of Palæozoic rocks and the Pre-Cambrian old land north of Georgian bay and the North Channel, is very marked. Quite unlike the topography just described, the Pre-Cambrian rocks rise in rounded hills, some reaching an elevation of 1,100 feet, or even more, above Lake Huron. Water, in general, occupies the area between the Pre-Cambrian and the Silurian regions, but numerous islands occur, and occasionally exhibit the two systems of land forms in juxtaposition. The old land surface is the result, in part, of Pre-Cambrian sculpturing, and in part, of post-Silurian erosion after the Palæozoic sediments were stripped from its surface. The land forms to the south are the result of the wearing back, during post-Silurian time, of the edges of alternating hard and soft sedimentary and nearly flat-lying formations.

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[1] The Geol. Surv. of Can., Report of Progress from its commencement to 1863.

[2] Bell, Robt.—Report on Manitoulin Islands: Geol. Surv. of Can., Report of Progress, 1863–66, pp. 165–179.

Report on Grand Manitoulin, Cockburn, Drummond, and St. Joseph islands: Geol. Surv. Can., Report 1866–69, pp. 109–116.

Report on the Geology of the French River sheet, Ont., with map of the eastern part of the Manitoulin island: Geol. Surv. Can., part I, Annual Report, vol. IX.

Map of the western part of Manitoulin published by Geol. Surv., Can., 1907.

[3] Geol. Surv., Can., Report of Progress from 1863–1866, p. 165.

General Geology.

Table of Formations. Manitoulin islands.

Quaternary	Recent		Soil.
	Glacial		Stratified sand and gravel; glacial boulders; boulder till.
Palæozoic	Silurian.		
		Lockport ("Niagara"). dolomite	Thin-bedded, to thick-bedded, and massive dolomite. Thickness, 240+ft.
		[1]Cataract formation ("Clinton")	Cabot Head member; red shale. Thickness, 27 to 66+ft.
			Manitoulin member; thin-bedded to thick-bedded, buff-coloured, dolomite. Thickness, 50 to 60+ft.
	Ordovician	Cincinnati group	Thin-bedded limestone and soft grey shale. Thickness, 435±ft.

CINCINNATI GROUP

The uppermost formation of the Cincinnati group is the Richmond, which consists of interbedded soft shales and thin limestones with 5 or 6 feet of soft green shale at the top. At Cabot head, soft red shale underlies the green shale conformably. About 20 feet below the Silurian, is a well-marked limestone horizon which contains many *Stromatocerium* remains. There is no transition between the Richmond and the overlying Silurian beds, for, while the former are calcareous shales the latter are dolomites which, although slightly argillaceous near the base, rest with a sharp contact upon the Ordovician green shales. Moreover, the two faunas have almost nothing in common.

CATARACT FORMATION

Manitoulin member

The basal dolomite strata of the Silurian on Manitoulin island, rest with apparent conformability upon the top of the Richmond formation. Near the base of the Manitoulin member of the Cataract formation, the dolomite is thin-bedded and argillaceous; midway up, thick beds and massive dolomite occur; and thin beds are again present near the top. Bryozoan and coral reefs, several yards in diameter, frequently occur within the upper 20 feet, and appear to have caused local thickening of the dolomite. In the lower, shaly, argillaceous dolomites, ramose bryozoa are plentiful, and about 10 feet above the base, *Leptaena rhomboidalis* (Wilckens) has been sparingly found. The greatest abundance of fossils[2] occurs in the upper beds and includes—*Zaphrentis bilateralis* (Hall), *Diphyphyllum multicaule* (Hall), *D.* cf.*huronicum*, Rominger, *Acervularia*

[1]The name *Cataract* was proposed by Professor Charles Schuchert, in a paper read before the 1912 meeting of the Palæontological Society of America, the name being derived from the locality in Ontario where the formation is well exposed. For the upper member the writer recently proposed the name *Kagawong*. This was preoccupied by A. F. Foerste who applied it to an upper Richmond member. *Cabot Head* was proposed by A. W. Grabau* for the red and grey Cataract shales of the mainland of Ontario and the name is here extended to cover the red shales of Manitoulin island. The name *Manitoulin* has been proposed by the writer for the lower member of the Cataract.

*Bull. Geol. Society of America. Vol. 24, No. 3, Sept. 1912, p. 460.

[2] The fossils mentioned in this report were identified by the writer with the assistance of E. M. Kindle.

gracilis (Billings), *Favosites niagarensis*, Hall, *Halysites catenulatus* var. *microporus*, Whitfield, a *Stromatoporoid*, *Apiocystites tecumseth*, Billings, [1]*Pachydictya turgida*, Foerste (?) [1]*Hallopora magnopora* (Foerste), *Schuchertella subplana* (Conrad), *Orthis flabellites*, Foerste, *Rhipidomella hybrida* (Sowerby), *Platystrophia biforata* (Schlotheim), *Camarotoechia neglecta* (Hall), *Atrypa* cf. *marginalis* (Dalman), *Anoplotheca planoconvexa* (Hall), *Whitfieldella nitida*, Hall, *Cyclonema concellatum*, Hall.

The guide fossils to the Cararact formation are *Pachydictya turgida*, *Hallopora magnopora*, *Atrypa* cf. *marginalis*, and *Anoplotheca planoconvexa*.

Accurate measurements of the thickness of this member are difficult to make owing to the small inclination of the strata, the drift and soil cover concealing much of the country, and the eroded condition of the rock surfaces where they are exposed. Cliffs of the Manitoulin dolomite measure 50 feet in height in a number of localities, and as these exposures are incomplete at top and bottom, there is reason to believe that the true thickness of the dolomite is 60 feet or more.

The Cataract formation along the south shore of Georgian bay has the same general characteristics as on Manitoulin island. Near the top of Collingwood mountain, the dolomite, which is only 11 or 12 feet thick, contains the following fossils: *Zaphrentis* sp., *Dalmanella elegantula* (Dalman), *Leptaena rhomboidalis* (Wilckens), *Strophonella striata* Hall, *Platyostoma* sp., *Calymene vogdesi*, Foerste?

At Owen Sound the dolomite is about twice as thick as at Collingwood, but at Cabot head it again measures 11 or 12 feet.

Cabot Head Member

The Cabot Head shale member of the Cataract formation, on Manitoulin island, has a clayey texture, and is generally of an iron red colour. Some green discoloration occurs near the top, due to leaching and consequent reduction of the iron minerals. No fossils have been found in it.

One continuous section of red shale on the road between Kagawong and West bay is at least 66 feet thick, but the normal thickness of shale on the eastern part of Manitoulin island is probably less than half that amount, or about 30 feet.

Near Collingwood, greenish-brown and red arenaceous shales containing bryozoa succeed the Manitoulin dolomite, but their exact thickness was not determined. The bryozoa, as identified by Dr. R. S. Bassler from material collected by Dr. A. F. Foerste near Meaford, are: *Phaenopora constellata*, Hall, *P. explanata*, Hall, *Sceptropora fustiformis*, Ulrich, *Phyllopora angulata*, Hall, *Helopora fragilis*, Hall. Most of these forms are characteristic of the Cataract formation.

Synopsis of the Cataract Formation

It will be seen that the Cataract dolomite reaches its greatest thickness (50 to 60 feet) on Manitoulin island; the firm, red bryozoan shale is not seen on Manitoulin, and the soft red unfossiliferous shale which was not observed south of Cabot head, is nearly constant in thickness (from 24 to 30 feet) in most localities where measurements were made, but attains more than twice that thickness on parts of Manitoulin island.

In a paper on 'The Cataract, a New Formation at the Base of the Silurian in Ontario and New York,' read before the 1912 meeting of the Palæontological Society of America, Professor Charles Schuchert describes his new formation as including the following: the Whirlpool sandstone and the overlying grey

[1] Identified by S. R. Bassler.

shale as exposed at Niagara Falls, but not the upper mottled sandstone and the grey band; all but the upper 10 or 11 feet of what has been called Clinton at Cataract, and the Forks of the Credit, Ontario; and the so-called Clinton of southwestern Ontario and the Georgian Bay region.

GREY TO GREEN SHALE HORIZON AT THE BASE OF THE LOCKPORT DOLOMITE

On Manitoulin island, about 5 or 6 feet of interbedded hard and soft green shale lie between the red Cabot Head shale and the Lockport dolomite. The lower beds of the dolomite are thin and argillaceous, and contain *Pentamerus oblongus*. The same conditions hold for Fitzwilliam island, where at the north-east extremity, the sequence upward from the red clay-shale is: 2 feet of soft green shale, 1 foot of hard green shale, and 3 feet of soft green shale immediately below thin-bedded dolomite, which exhibits mud-cracking in shaly beds. A short distance above the zone of mud-cracks *Pentamerus oblongus* occurs.

In the section seen at Cabot head the shales are much obscured by talus. However, between the Manitoulin and the Lockport dolomites, there is a series of shales, mostly of grey and green colour with a little red interspersed near the top. Lithologically they consist of soft, clay shale interbedded with firm shale. In thickness, they measure about 50 feet. Near the base of the Lockport dolomite, mud-cracks occur in thin pea-green shale beds and a few fossils were obtained from thin dolomitic beds in a zone between 10 and 25 feet below the top of the shales. The fauna is poorly preserved but includes a small cup coral, bifoliate bryozoa, *Favosites niagarensis*, Hall(?), *Whitfieldella nitida*, Hall(?), *Camarotoechia* cf. *neglecta* (Hall), *Cornulites* sp. and *Leperditia* sp.

LOCKPORT DOLOMITE

If we accept the interpretation of the Cataract formation as given by Schuchert, there must be a long time interval represented between the deposition of the Cabot Head shale of Manitoulin island and the Lockport dolomite—for by definition the Medina, from the *Arthrophycus* beds up, and according to observation the Clinton, and the Rochester, are absent. The positive evidence depends mainly upon the local variations in character and thickness of the shale beds. How much these differences may be due to erosion and how much to differences in the conditions of sedimentation it is difficult to state in the absence of observed angular unconformities, or critical faunal data.

The formation in Ontario which is correlated on fossil evidence with the Lockport of New York state, has the same general characteristics throughout the Province. It is, wherever present, the great cliff forming horizon.

On Manitoulin island, the Lockport consists of thin-bedded to thick-bedded and massive dolomite. At the base, immediately above the red Cabot Head shale, the dolomite is thin-bedded and argillaceous, and a short distance up contains numerous *Pentamerus oblongus*. In the 240 foot section measured north of Fossil hill, a sparing coral fauna starts about 80 feet up in the formation and attains its maximum about 100 feet above the base. The upper 30 feet of the Lockport is massive and nearly unfossiliferous. Some of the most characteristic fossils from the Lockport of Manitoulin island are: *Zaphrentis umbonata*, Rominger, *Cyathophyllum radicula*, Rom., *Omphyma verucosa*, Rafinesque and Clifford, *Chonophyllum belli*, Billings, *Arachnophyllum striatum* (d'Orbigny), *A. pentagonum* (Goldfuss), *Diphyphyllum multicaule* (Hall), *Favosites Gothlandica* (Lamark), *Cladopora laqueata*, Rominger,[1] *C. crassa* (Rominger), *Coenites laminata* (Hall),

[1] Identified by L. M. Lambe.

Syringopora retiformis, Billings, *Halysites catenulatus*, Linnaeus, *Heliolites pyriformis*, Guettard, *H. megastoma*, McCoy, *H. interstinctus* (Linnaeus), *Orthis flabellites*, Foerste, *Pentamerus oblongus*, Sowerby, *Stricklandinia* sp. nov., *Platyostoma* sp., *Atrypa* sp. undet., *Orthoceras* sp.

An interesting and quite different fauna was discovered at a zinc prospect near Wiarton (see under Zinc Prospect). The rock, which is massive, though porous, dolomite, appears to represent a higher horizon than that at Wiarton (which probably includes the lower 110 feet of the Lockport formation, and is characterized by scattered corals, altough nearly unfossiliferous near the top), or along the Georgian Bay side of the Bruce peninsula, and the fauna is unusual for Ontario containing, as it does, a number of species of cephalopods, some of which are of large size. The following fossils were recognized: *Rhynchotreta cuneata americana* (Hall)? *Actinopteria* sp. undet., *Amphicoelia* cf. *costata*, Hall and Whitfield, *Stropheodenta* cf. *profunda*, Hall, *Orthoceras* (more than 5½ in. diam.) *Orthoceras* cf. *wauwatosense*, Whitfield, *Dawsonoceras annulatum* (Sowerby), *Proterioceras* sp. undet., *Trochoceras costatum*, Hall(?), and poorly preserved corals of *Diphyphyllum* type.

The above fauna, so far as it goes, is in harmony with the 'Niagara' of Racine, Wisconsin, and Bridgeport, Ill[1].

It has been suggested that the sparsely fossiliferous, massive dolomite about South Baymouth, Providence bay, and Fitzwilliam island might be Guelph[2]. The localities referred to on Manitoulin island were all visited except that on the southeastern extremity of the island. The rock at these localities differs little from the typical Lockport dolomite, but is massive in many places, and along the lake shore weathers out into small pits, 1 to 2 inches in diameter and at varying distances from each other. Fossils are scarce in the massive beds, but occur in the thinner-bedded rock almost as commonly as in the typical Lockport. A satisfactory identification of the fauna is not possible because of its poor preservation, but *Syringopora verticellata*, Goldfuss, *Favosites niagarensis*, Hall, and *Halysites catenulatus*, Linnaeus, have been definitely determined, and *Stromatopora concentrica*, Goldfuss, *Plasmopora elegans* (Hall) (?) *Zaphrentis bilateralis* (Hall), *Syringopora* sp., *Favositis venustus* (Hall), and *Pleurotomaria* cf *perlata* Hall, are thought to have been recognized. Other obscure forms probably represent bryozoa and crinoid columns.

It will be seen that outside of *Pleurotomaria* cf. *perlata*, there are no distinctively Guelph fossils among those mentioned. Moreover, large gasteropods similar to that above mentioned occur in lower beds of the Lockport along the north side of Fitzwilliam island, and elsewhere. Therefore, there is no evidence for the presence here of the Guelph horizon, and we, therefore; confirm the statement of Dr. H. M. Ami that 'as far as I could find, not a single characteristic species of the Guelph formation occurs, while abundant evidence was noted to refer the rocks of the whole area to the Niagara formation'[3]. Further, the beds exposed along the south shore of the island appear to belong in the Lockport as seen in the section north of Fossil hill.

In the opinion of the writer, based upon the studies in the field, this section near Fossil hill represents practically all of the Lockport formation of eastern Manitoulin that still remains after untold ages of erosion. There is reason to believe that the dip of the strata, taken by Murray and Bell as averaging 40 to 50 feet per mile, changes in the south half of the island, where the beds are undula-

[1] Twentieth Annual Report of the Regents of the University of the State of New York, etc., 1867.

[2] Bell, Robert.—Report of Progress, 1863-66, p. 176.
Report Geol. French River Sheet, Annual Report, vol. IX, part I, p. 24.

[3] Geol. Surv., Can., Annual Report, New Series, vol. XI, 1898, p. 179A.

tory. Thus any estimate of the thickness of the Lockport formation based upon breadth of outcrop and dip of strata is liable to serious error. Its complete thickness, however, is probably somewhat greater than 240 feet as measured north of Fossil hill.

Zinc Prospects Near Wiarton.

Zinc prospects have been opened up about 4 miles from Wiarton on the north half of lot 30, concession II, township of Albermarle East, Bruce peninsula. Part of an afternoon was spent at the open-cut in charge of Mr. G. B. Bourne, of London, Ontario. Thanks to the assistance of this gentleman, the writer was able to obtain considerable information relating to the formation at this place and the occurrence of the ore. As already stated elsewhere, the rocks are of Niagaran age, but represent higher beds than those exposed at Wiarton or at most localities along the east part of Bruce peninsula. The dolomite is very porous, especially in the fossiliferous portions.

Zinc blende occurs filling pore spaces and cavities, and partially replacing fossils and the country rock. The greatest accumulation of ore was found in cavities open to the surface and evidently dissolved out by meteoric water. Loose ore was mixed with pebbles and earthy materials, and in one place as much as 110 pounds of ore were obtained from a single pocket.

Prospecting was begun in 1910 and, when visited, the open-cut was about 100 feet long, 30 feet wide, and 33 feet deep. Ore was obtained down to 20 feet in depth, below which no ore was observed although these lower beds are rather more porous than in the ore horizon. In all, a car load lot of ore was shipped from the prospect. The blende is said to assay 69·76 per cent zinc.

The zinc blende appears to be confined to the surface beds of the dolomite, and there are no indications of any special conditions which might lead to important ore concentration. In these circumstances new ore bodies are to be looked for on the surface rather than at lower levels.

THEDFORD AND VICINITY, ONTARIO.

(*M. Y. Williams.*)

Scope of Work and Acknowledgments.

During the field season of 1912, fourteen days were devoted to work on the Devonian formations in the vicinity of Thedford, Lambton county, Ontario. Sections were measured by means of a hand level, supplemented by barometric readings. The work was carried on at two periods, the first being from July 27 to August 1, inclusive, and the second from October 9 to 16, inclusive.

The writer is indebted to Professor Charles Schuchert, of Yale University, for guidance and instruction in the field during the first visit to Thedford.

The Area Studied.

Thedford is situated in Lambton county, Ontario, about 40 miles east of Sarnia, on the main line of the Grand Trunk railway from Sarnia to Toronto via Guelph and Stratford. The localities visited are: Marshall's mills, Rock glen, and No. 4 hill, situated along the Aux Sables river east of the village of Arkona which is about 5½ miles south of Thedford; the brick-yard north of Thedford, the railway cut just east of the town and some small excavations and quarries to the north of it; and Kettle and Stony points northwest of Thedford on the Lake Huron shore.

Previous Work.

In 1863, Sir Wm. Logan[1] described the Hamilton formation of Ontario. He recognized the shales of Kettle point as of Genesee age and finding no Marcellus shales or Tully limestone, he included all between the Corniferous and the Genesee in the Hamilton formation. From the evidence of bore-holes, he estimated the Hamilton to be 300 feet in thickness. The same author described a 133-foot Hamilton section occurring in concession III, Bosanquet, lot 25, and figured a number of fossils.

For the palæontology of the Hamilton formation of Thedford, the reader is referred to the works of H. A. Nicholson[2], J. F. Whiteaves[3], S. Calvin[4], and Hervey W. Shimer[5] and Amadeus W. Grabau[6].

The last-mentioned publication gives the most detailed account of the stratigraphy about Thedford and includes a very complete list of fossils, with the description of several new species and varieties. The latest publication on the stratigraphy of the Hamilton of western Ontario, is that by C. R. Stauffer[7].

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[1] Geology of Canada, 1863, pp. 382-387.
[2] Palæontology of the Province of Ontario, Toronto, 1874.
[3] Contributions to Canadian Palæontology, vol. 1, pp. 91-125.
[4] Contributions to Canadian Palæontology, vol. 1, pp. 361-418.
[5] Am. Geologist, vol. I, 1888, pp. 81-86.
[6] Geol. Soc. Am., Bull., vol. XIII, pp. 149-186, 1902.
[7] Summary Report, Geol. Surv., Can., 1911, pp. 269-272.

Topography.

The country about Thedford is generally level, hills and valleys occurring mostly in the vicinity of the main drainage channels. The Aux Sables river has entrenched its course 60 feet or more below the land surface, but the stream bed, though well graded, has not developed meanders. The secondary drainage channels are youthful and descend over falls of considerable height a score or more rods from their confluence with the river. Interstream mounds and rolling hills are occasionally present.

General Geology.

Table of Formations

Quaternary	Recent	Soil.
	Pleistocene or Glacial	Unsorted clay-gravel deposits 3 to 5 feet thick.
Palæozoic	Devonian	
	Ohio shales	Black carbonaceous shales, containing remains of plants, and including numerous spherical masses of carbonate of lime, in radial development.
	Hamilton formation (estimated to be 300 ft. thick) (Exposures studied probably represent the upper 100 ft. of the formation).	Alternating limestone and soft grey shale. Numerous fossil remains, commonest being *Spirifer mucronatus*.

THE HAMILTON SECTION AT THEDFORD

A section of about 80 feet of Hamilton shales and limestones is exposed in the vicinity of Thedford and along the banks of the Aux Sables river. The thickest sections are to be seen along the river at Rock glen and at a locality known as "No. 4 hill" about 1¼ miles north of Arkona. Excellent collecting grounds occur at Marshall's mills, east of Arkona; and also in the vicinity of Thedford at 'the Brickyard', in a railway cut east of the town, and in some small gravel pits and a quarry north of the railway cut. Limestone beds, probably representing the upper 10 to 20 feet of the Hamilton formation, occur at Stony point on the Lake Huron shore northwest of Thedford.

The following section is made up from measurements taken at Marshall's mills, Rock Glen, and No. 4 hill, and is given in descending order.

Zone 7. Shale poorly exposed. Thickness 4 to 5 feet.
Zone 6. Limestone with shale partings. Thickness about 14 feet.
Zone 5. Shales and argillaceous limestones. Thickness 35 to 40 feet.
Zone 4. Shale. Thickness about 5 feet.
Zone 3. "Encrinal" limestone. Thickness 2 feet.
Zone 2. Black carbonaceous shale 6 inches.
Limestone, 4 inches.
Zone 1. Shales. Exposed thickness, 35 feet.

The shales which comprise the most of the thickness of the Hamilton formation, are very soft and weather to fine blue clay; the limestones are blue grey in colour and are generally firm and resistant.

The lower shales (zone No. 1) are not highly fossiliferous except in a few beds. The fauna characterizing them includes: *Arthroacantha punctobrachiata*, Williams, *Stropheodenta demissa* (Conr.), *Chonetes scitula*, Hall, *Spirifer mucro-*

natus var.[1] *arkonensis*, *Platyceras bucculentum*, Hall, *Tentaculites attenuatus*, Hall, *Bactrites obliqueseptatus* var. *arkonensis*, Whiteaves, *Tornoceras uniangulare* (Conr.) *Phacops rana*, Green.

At the base of the upper division is a 4-inch bed of limestone succeeded by 6 inches of black carbonaceous shales (No. 2). The black shale is very persistent and always contains many compressed specimens of *Leiorhynchus laura* (Bill).

The limestone of zone No. 3 has been referred to in previous papers as the 'encrinal limestone.' Some of the common fossils are: *Craspedophyllum archiaci*, (Bill.), *Favosites turbinata*, Bill., *Leiorhynchus laura* (Bill.)

The shale of zone No. 4 contains a rich coral fauna, Heliophyllum and Cystiphyllum being very abundant. The commonest fossils are: *Zaphrentis prolifica*, Bill., *Heliophyllum halli*, E and H., *Cystiphyllum vesiculosum*, Goldf., *Favosites placenta*, Rom., *Cladopora frondosa* (Nicholson), *Striatopora linnaeana* Bill., *Trachypora elegantula*, Bill., *Alveolites goldfussi*, Bill., *Fenestella arkonense*, Whiteaves, *Pholidostrophia iowaensis* (Owen), *Rhipidomella penelope*, Hall, *Camarotoechia thedfordensis*, Whiteaves, *Spirifer mucronatus* var. *thedfordensis*, S. and G., *Cyrtina hamiltonensis*, Hall, *Altrysis fultonensis* (Swallow), *Platyceras subspinosum*, Hall, *Heliophyllum confluens*, Hall.

The shales and argillaceous limestone of zone No. 5 contain comparatively few fossils. *Spirifer mucronatus* var. *thedfordensis* S. and G., occurs in increasing abundance towards the top. *Chonetes lepida*, Hall, C. *vicina* (Castelneau), *Pterinea flabellum* (Conr.), *Phacops rana*, Green, and *Dalmanites boothi* (Green), are reported by Shimer and Grabau as occurring in the lower beds.

The limestone of zone No. 6 consists of heavy beds separated by shale partings. Some of the characteristic fossils are: *Ceratopora intermedia* (Nich.) *Stropheodonta concava*, Hall, *Leiorhynchus laura* (Bill.), *Spirifer mucronatus* var. *thedfordensis*, S. and G., *Athyris fultonensis* (Swallow).

Shale (No. 7) is poorly exposed at the top of the section and appears to be nearly barren of fossils.

The lower shales of the above section may be seen at any of the collecting grounds visited along the Aux Sables river. Zones 2, 3, and 4 may be seen along the Aux Sables river and also at the brick-yard near Thedford. Zones 5 and 6 are well exposed along the Aux Sables river. The upper 15 or 16 feet of zone No. 5 and the lower 9 or 10 feet of zone No. 6 are exposed to good advantage in the railway cut east of Thedford, where numerous Spirifers and other brachiopods may be found.

The small gravel pits to the north of the railway afford fair collecting from the lower part of Zone No. 6.

Zone No. 7 is best represented at the top of the falls near No. 4 hill.

Hunniford's quarry, some distance north of the gravel pits, is said to be an excellent collecting ground for the fossils of zone No. 4; *Pentremites* and some of the rarer fossils are said to occur there. *Microcyclas discus* is found to best advantage about one-third mile downstream from the brick-yard along the east bank of the stream where *Ancyrocrinus* and *Pentremites* have also been found.

It is not known how much of the Hamilton section is lacking between the highest beds observed at Number 4 hill and the upper beds of the formation exposed at Stony point, but from the general attitude of the strata there may not be more than a score of feet. At the latter place a low anticline bows the strata up above the level of the lake. Farther west, limestone is exposed along the crest of a small anticline, and from that point west no more limestone is observed.

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[1] This and the following varieties of *Spirifer mucronatus* have been identified by Shimer and Grabau from the horizons named.

The (Ohio) shale outcrops on the west side of Kettle point, apparently resting upon the Hamilton beds represented by the outcrops exposed along the shore.

The limestones of Stony point are separated by green shale partings, and numerous fossils occur partly embedded in the shale and partly in the limestone. The following species have been recognized: *Cystiphyllum vesiculosum*, Goldf., *Ancyrocrinus bulbosus*, Hall, *Fenestellid* bryozoa, [1]*Stropheodonta concava*, Hall, [1]*S. demissa* (Conr.), [1]*S. perplana* (Conr.), [1]*Pholidostrophia iowaensis* (Owen), *Spirifer granulosus* (Conrad), *S. mucronatus* (Conrad), *Tentaculites bellulus*, Hall, [1]*Phacops bufo* (Green).

THE OHIO SHALES

At Kettle point, a section of 10 or 12 feet of dark grey to black carbonaceous shale is exposed in a low cliff. The rock is thin-bedded and cleaves into thin plates. The fossils of the shale include glistening carbonaceous remains of wood, hexagonal markings probably representing the remains of lepidodendron, sporangia of sea weed (*Sporangites huronensis*), conodonts, and lingulae.

Of greater popular interest than the fossil remains are the so-called 'kettles', from which the Point derives its name. A large number of nearly spherical concretions once lay scattered along the beach, having been released from their shale surroundings by the erosion agencies at work along the shore. To-day, only the larger kettles are left, many of the smaller ones decorating the lawns of residents in the neighbouring villages. Where the concretions are still in place, the shale beds are bowed out of normal position by them, those beds meeting the concretions at right angles to their surfaces being entirely cut off. Examined in cross-section, the concretions are seen to be made up of radiating growths of a mineral which starts from an amorphous, shaly centre. Zones some distance from the centre are also amorphous, the mineral growth continuing outside of them again. A specimen of the mineral was examined in the office by Mr. R. A. A. Johnston and the writer, both megascopically and in thin section under the microscope. The mineral is calcite which has included organic material, and some kaolin or clay is also present. A slide cut parallel the radial growth, shows, between crossed nicols, extinction which is approximately parallel the direction of growth. A slide cut normal to the direction of growth shows irregular areas of calcite which extinguish at different angles.

SURFICIAL DEPOSITS

Above the rock formations are a few feet of unsorted clay and gravel of local origin. Some of the pebbles of limestone are fairly smooth as though worn by wave action; on the other hand, well-preserved fossils are frequently found which show almost no wear.

The soil of the country is a dark rich loam which makes Lambton county noted for its mixed farming and fruit raising.

[1] Not collected but recognized in the field by Professor Schuchert.

NOTES ON THE ORISKANY SANDSTONE AND THE OHIO SHALE OF THE ONTARIO PENINSULA[1]

(*E. M. Kindle*)

Oriskany Sandstone.

Stratigraphic Relations and Distribution.—The Oriskany sandstone lies between the shales and limestones of the Salina formation below and the Onondaga limestone above. The Oriskany sandstone of southern Ontario is confined, so far as known, to a narrow belt of territory between the Niagara river and the western boundary of Haldimand county. The detached areas of the Oriskany sandstone in Haldimand and Welland counties represent the most westerly of a line of outcrops of the formation which extends almost across the state of New York from west to east, and south along the Hudson River valley, across Pennsylvania, Maryland, and the greater part of Virginia, a total distance of about 800 miles. The formation has its maximum thickness in Pennsylvania where it is in many places from 200 to 300 feet thick. From its maximum thickness in the Middle Alleghany region, the Oriskany thins to the north and northeast, disappearing completely from the section at many points in New York.

The Oriskany sandstone is highly irregular both in thickness and distribution in Ontario as it is in central New York. It is frequently absent from sections showing the Onondaga limestone which belongs above it. Where it is present it may thin from a thickness of 15 feet or more to a few inches in a distance of a few rods. This probably results in large part from the Oriskany sandstone filling troughs of erosion in the Salina beds. The accompanying diagrammatic figure shows the relations of the Onondaga limestone and subjacent Oriskany and Salina beds near Decewsville, Ontario. An excavation about 200 feet northeast of the Oneida Sand Company's quarry 2 miles northwest of Decewsville, shows the following section:—

Decewsville Section.

Onondaga limestone	2 feet.
Oriskany sandstone	17 inches.
Salina limestone	30 feet +

In the quarry less than 200 feet from the above section the Oriskany sandstone has thickened to nearly 20 feet as shown in the diagram (Figure 8).

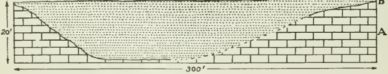

Fig. 8.—Diagram showing relations of Onondaga limestone and subjacent Oriskany and Salina beds near Decewsville, Ontario.

[1] The faunas of the Oriskany sandstone have been studied recently in considerable detail by Dr. C. R. Stauffer, whose results will appear elsewhere in a report of this Survey. It is only necessary, therefore, to refer briefly here to some of the physical features of this formation.

The marked disconformity which exists between the Oriskany and the subjacent beds, as shown by the figure, is the most important factor in determining the local character and thickness of the sandstone in different areas. Where the Oriskany sea encountered considerable troughs, or depressions, in the surface of the old submerged Silurian land surface they were filled with the Oriskany sands, and these have more generally escaped subsequent erosion than the sediments of the inter-trough areas. The remnants of the Oriskany sediments which have escaped erosion and remain in Ontario thus have a distinctly lenticular character. The formation is thus highly irregular in distribution and thickness.

Economic Geology.—The Oriskany sandstone is of economic value both as a building stone and as a source of glass sand. Where the rock is hard and well cemented it often affords an excellent building stone. The softer grades of the sandstone which are sufficiently free from iron and other colouring matter are available for glass sand. This formation has long been the principal source of sand for the manufacture of glass throughout the middle Alleghany region. The Oneida Sand Company is now utilizing this sandstone for this purpose. Its quarry is located northwest of Cayuga, 2½ miles, where about 14 feet of the sandstone is quarried, crushed, and washed, for glass sand.

Ohio Shale.

General Description and Correlation:—The fissile black shales outcropping at Kettle point on Lake Huron and along the Sydenham river are the youngest Palæozoic beds which are known from surface outcrops in southern Ontario. They belong to the same stratigraphic and faunal province as the Ohio shale of northern Ohio. These black shales occur over a considerable area in the Ontario peninsula to the west of London. Owing to the heavy cover of drift the limits of this area are not definitely known.

The lithologic and faunal characteristics of the fissile black shales of the upper Devonian on the Ohio and Ontario sides of Lake Erie are so closely alike as to leave no doubt of their identity. I have pointed out elsewhere[1] that in Ohio the presence or absence of spherical concretions affords an easy means of distinguishing the upper and lower members of the Ohio shale known respectively as the Cleveland and Huron shale. 'Detailed study of a large number of sections from Lake Erie to Kentucky has shown that certain lithologic features characterize the upper and lower portions of the Ohio shale group and afford very important aid in identifying them. It has been found in studying a considerable number of sections that the lower part of the black shales above the Olentangy shale is everywhere characterized in Ohio by spherical concretions often of large size. Concretions of this type are entirely unknown in the Cleveland shale, both in its typical area and outside of it. It is proposed, therefore, to limit the term Huron shale to those beds of the Ohio shale exposed on the Huron river, at Rye beach and elsewhere, in which the spherical concretions occur, and the Cleveland shale to the higher beds in which they do not occur and in which the cone-in-cone structure does occur. The spherical concretions are a persistent feature of the lower or Huron shale as far south as the first tier of counties in Kentucky'. The peculiar spherical concretions which characterize the basal division of the Ohio shale occur abundantly in the lower part of the Ohio shale at Kettle point, Ontario. These, together with the presence of certain fossils which characterize the Huron shale of Ohio, plainly indicate the identity of the black shale at Kettle point with the Huron shale of the Ohio section.

[1] The stratigraphic relations of the Devonian shales of Northern Ohio. Am. Jour. Sci., vol. 34, 1912, p. 198.

About 10 feet of fissile black shale is exposed in the lake shore at Kettle point. The lowest beds exposed show numerous markings apparently representing worm-trails but possibly fucoidal in origin. Occasionally fragments of large plants occur here, probably representing Pseudobornia. The other organic remains which occur here may be listed as follows:—

Lingula ligea Hall.
Polygnathus dubius Hinde.
Polygnathus universus Hinde.
" *radiatus* "
" *? serratus* "
" *palmatus* "
Rhadinichthys sp. undet.
Sporangites huronensis Dawson.

The minute discs of the last named plant fossils occur at all horizons of the shale in countless numbers. These are amber-coloured spoor-cases which are scarcely more than a hundreth of an inch in diameter. These beds contain also, according to Sir William Dawson[1], stems of '*Calamites inornatus* (*Pseudobornia inornatus*) and of a *Lepidodendron*, obscurely preserved, but apparently of the type of *L. veltheimanum* and possibly the same with *L. primaevum* of Rogers' The *Lingula ligea* of this list is a common and characteristic fossil of the Huron shale of Ohio and of the lower part of the Portage of New York. *Polygnathus palmatus* is one of the conodonts which appears to be confined to the Huron member of the Ohio shale and is unknown above the Genesee of New York. These two species, therefore, point very definitely to the identity of the beds at Kettle point with the Huron member of the Ohio shale and with a horizon of the New York section embracing probably both the Genesee and the Portage.

Two other outcrops with spherical concretions which doubtless also represent the Huron shale are mentioned by Logan.[2]

The spherical concretions appear to be entirely wanting in the outcrops of the black shale on the Sydenham river east of Alvinston which I have examined. They agree in this and other respects with the Cleveland member of the Ohio shale and doubtless represent the Cleveland shale of the Ohio section. Conodonts and plant fragments are rather common in the outcrop in the bed of the stream just east of Alvinston, which is representative of this upper portion of the Ohio shale. The total thickness of the Ohio shales indicated by well records appears to be in the neighbourhood of 200 feet.

Nothing is known from outcrops of the beds which lie above the black shales exposed in the Sydenham River outcrops. Certain drill records, however, indicate the presence in Moore township of 20 to 50 feet of greenish shales and sandstones which have been inferred by Dr. Stauffer[3] to represent probably Portage and Chemung beds. It appears to me probable, however, that these beds are the Ontario representatives of beds of a similar lithologic type which on the south side of Lake Erie lie immediately above the Ohio shale and are called the Bedford shale. It is possible too that these light coloured beds represent one of the blue shale horizons of the Ohio shale which are conspicuous along the Huron river.

Economic Geology:—The rocks of Ontario contain no coal, but there is locked up in the bituminous black shales of the Ohio shale an immense volume of potential fuel. A sample of these black shales from Bosanquet, on Lake Huron, which was analysed by T. Sterry Hunt[4], lost by ignition in a closed vessel 12·4 per cent, and

[1] On Spoor cases in coals. Am. Jour. Sci., 3rd Ser., vol. I, 1871, pp. 258-263.
[2] Geology of Canada, Geol. Surv. of Can., Report of Progress, 1863, p. 388.
[3] Can. Geol. Surv., Dept. Mines, Summary Report for 1911 (1912), p. 272.
[4] Chemical and Geological Essays. The Scientific Pub. Co., N.Y. and London, 5th Ed., p. 179, 1897.

yielded by distillation in an iron vessel 4·2 per cent of oily hydrocarbons, besides a large quantity of inflammable gas and a portion of ammoniacal water. A similar black shale of the same geological age has yielded in experimental distillation from three samples obtained at different localities near New Albany, Indiana, U.S.A., results which are compared with the gas yield of Pittsburgh coal in the following table[1]:—

5 pounds of Pittsburgh coal	105 gallons of gas.
8·5 pounds of black slate	45 gallons of gas.
8·5 pounds of black slate, Ohio banks	50 gallons of gas.
8·5 pounds of black slate, Falling Run banks,	65 gallons of gas.

Tests of this shale at New Albany, Indiana, by the New Albany Gas Light and Coal Company are reported by the superintendent as follows:[2] 'I carbonized three tons of the New Albany black shale and obtained a yield of 2·20 cubic feet per pound of twenty-two candle power gas. Ordinary unenriched coal gas is about eighteen candle power. The quality of the gas, therefore, is better, and the yield 45 per cent of that obtained from Pittsburgh coal'. Distillation of the black shale at low temperatures will yield a variety of compounds. A large percentage of crude oil may be obtained from it by distillation at low temperature with small fuel expense. One of the by products of considerable value which could doubtless be obtained in the process of distillation of these shales is sulphate of ammonia. This valuable fertilizer which is one of the products of the oil shales of Scotland[3] is used extensively by agriculturists in Great Britain and elsewhere, particularly for growing the sugar beet.

Still another possible method of utilizing the fuel content of the black slates of southern Ontario consists in blowing the freshly pulverized slate with a blast into a furnace.

It is not within the province of this paper to consider the commercial questions involved in manufacturing oil or gas from the black shales of Ontario in competition with natural oil and coal gas. But it may be noted that the manufacture of mineral oil from carbonaceous shales has long been an extensive and profitable industry in Scotland[4] and Thuringia in spite of the low prices of American and Russian petroleum. Whether the fuel content of the black slates in southern Ontario is developed at an early or remote date the great economic value which these shales possess cannot be contested. When it is considered that these shales contain at least 10 per cent of combustible material and have a thickness amounting to about 200 feet in a portion of the region it will be seen that they represent an almost inexhaustible source of heat and light.

The gas and oil which may be quickly distilled from the black shale through the application of heat have been produced in considerable quantities during the lapses of ages by the much slower action of natural geological agencies. Where the texture of the associated beds and the geologic structure have been favourable for its conservation, the oil and gas generated by natural agencies have been preserved and may be extracted with the aid of the drill. The chief factors essential to the formation of gas and oil reservoirs are (1) porosity of the strata adjacent to the source of supply, (2) anticlinal or other structure which will cause local accumulation of gas and oil, (3) rock cover sufficiently impervious to prevent the escape into the air of the hydrocarbon products. The limestones at the base of the black shale are likely to afford beds sufficiently porous to act as gas or oil reservoirs.

[1] Ind. Dept. Geol. and Nat. Resources, 21st Annual Report, 1897, p. 113.
[2] *Ibid.*, p. 113.
[3] The oil-shales of the Lothians. Mem. of Geol. Surv. of Scot., parts I-III, 1912.
[4] Yearly output 60,500,000 gallons crude oil in 70 factories. Jour. of Gas Lighting, 1894, I, p. 973½; 1894, II.

On the south side of Lake Erie, in northern Ohio, the drill often reaches strong flows of gas in the Ohio shales. In Kentucky, wells sunk on an anticlinal axis sometimes afford good flows of gas at the contact with the black shale and limestones directly below them. Much detailed work must be done in southern Ontario before the structural features which determine the belts or areas most favourable to the accumulation of gas can be indicated. Most of the natural gas wells of Ontario have derived their supply from beds much lower than the Ohio shale. In fact all of the principal geological horizons above the Cambrian have afforded gas.

STRATIGRAPHY OF SOUTHWESTERN ONTARIO

(Clinton R. Stauffer)

General Statement.

In a previous summary report[1] it has been said that the Monroe series of the Detroit River section, and similar deposits along the Thames river and Lake Huron, have furnished a fauna with marked Devonian characteristics. It has seemed advisable, therefore, to devote some time to those rocks in connexion with the forthcoming report on the Devonian of southwestern Ontario. Accordingly, a few weeks were spent in the field, during the summer of 1912, collecting material and studying such outcrops of these beds as are accessible. Much additional time, however, was given to revisiting certain of the Devonian outcrops which had been examined during the previous season, since a study of the material then obtained seemed to demand more thorough collecting. Finally a visit was paid to the Port Colborne and Hagersville regions to collect additional material.

The Silurian Formations.

In Michigan the following subdivisions[2] of the Monroe beds have been made, and include somewhat more than 800 feet of sediments.

Monroe..........	Upper...........	Lucas dolomite. Amherstburg dolomite. Anderdon limestone. Flat Rock dolomite.
	Middle...........	Sylvania sandstone and dolomite.
	Lower...........	Raisin River dolomite. Put-in-Bay dolomite. Tymochtee shales. Greenfield dolomite.

Unfortunately only a small portion of this great mass of rock is usually exposed at any one place and the relationships of the various members must be inferred from the fragmentary knowledge which we now possess. The salt shaft at Oakwood, South Detroit, gives a very complete section of the Monroe. Here, however, the Amherstburg dolomite is said to be wanting[3]. This is the division of the Monroe which is traversed by the Stony Island dry cut at the International Boundary line in the Detroit river, and in which the fossils with the most marked Devonian characteristics occur. The structure of the bed-rock in the vicinity of Amherstburg and the 'dry cut' is such that there is some doubt whether it is possible for the Amherstburg dolomite to occupy the position which has been assigned to it in the above table, and whether after all it does not belong in the lower Monroe several hundred feet below the Sylvania sandstone. Sherzer and Grabau consider the Sylvania as dipping synclinally under the Detroit river[4],

[1] Summary Report of the Geological Survey for the year 1911 (1912), pp. 270, 271.
[2] Bull. Geol. Soc. Am., vol. 19, 1907, p. 566; also Mich. Geol. and Biol. Surv., Pub. 2, Geol. Ser. 1, 1910, p. 27.
[3] Mich. Geol. and Biol. Surv., Pub. 2, Geol. Ser. 1, 1910, p. 42.
[4] Bull. Geol. Soc. Am., vol. 19, 1907, p. 541.

and hence the position indicated for the Amherstburg dolomite. In the Stony Island dry cut (Livingston channel), which is about one mile in length, 105 feet of strata have been laid bare. The dip of these rocks is southward at the rate of about 100 feet per mile. At the south end of Bois Blanc island, the Sylvania sandstone outcrops in the river[1], and on shore, just south of Amherstburg, it lies under 25 feet of dolomite[2]; while at Caldwell Grove, about a mile east of the river, the Sylvania is overlain by 252 feet of dolomites and limestone with 8 feet of drift over all[3]. Wells to the eastward show the Sylvania under a still greater rock cover, while the topography of the land surface has changed but slightly. On Horse island and at several places to the southwestward on the Michigan side of the river, the Sylvania sandstone outcrops. At Trenton, opposite the middle of Grosse Isle, it lies under a rock covering of 215 feet, in addition to 75 feet of drift; and at Wyandotte, which is 5 miles north and a little east of Trenton, the Sylvania is overlain by 165 feet of dolomites and 75 feet of drift. Continuing northward from here, the Sylvania descends steadily until at Detroit (Stroh's brewery) it lies under 461 feet of shales, limestones, and dolomites, in addition to 154 feet of drift; and at Windsor it is covered by 535 feet of drift, limestone, and dolomite[4]. Over the distance in which these changes in the rock covering of the Sylvania are taking place, the land surface is relatively flat and the change in elevation is scarcely more than 50 feet. It seems possible, therefore, that the northward extension of the Cincinnati anticline carries the Sylvania sandstone horizon above the level of the middle of Detroit river to some point near the north end of Grosse Isle, where it dips below the stream and passes rapidly under rock cover. If this be the case, the width of the truncated portion of the anticline has here dwindled to about 4 miles. Such a structure for the bed-rock is further suggested by the westward dip in the Sibley quarries at Trenton, Michigan, and by the eastward dip on the mainland to the east of the river as indicated by an outcrop of Onondaga limestone near the shore of Lake Erie, about a mile to the east of the mouth of Detroit river, and by various wells to the north of Amherstburg. Such a rock structure as here indicated would bring the Amherstburg dolomite into the lower Monroe and account for its apparent absence at its supposed horizon in the salt shaft at Oakwood, although it should be found at the lower level.

Rev. Thomas Nattress, of Amherstburg, is the originator and chief promoter of the above conception of the rock structure in Detroit river at Amherstburg[5], although he may not agree to all the details here set down. Nattress is much interested in the local geology and probably knows it better than any other person because he has had better opportunities to observe it and has given a greater amount of time to working it out. He has been in close touch with Government engineers, inspectors, and dredge men working on the river during at least the past twelve years and has superintended the removal of a large number of drill cores on both sides of the river. In addition he has collected from the material removed from the bed of the river, as well as from the local quarries, and has made trips to the islands of Lake Erie. He has thus acquired a great mass of information, much of which is beyond the possibilities of most other men. His interpretation, therefore, when properly supported by facts, must bear considerable weight with those who are giving attention to the problem.

On the other hand, it must be pointed out that the occurrence of such large

[1] Nattress, Rev. Thomas, Twelfth Report Mich. Acad. Sci., 1910, p. 49.
[2] *Idem*, p. 50.
[3] Brummel, H. P. H., Geol. Surv., Canada, Annual Report, vol. v, 1892, p. 79 Q.
[4] See Board of Geol. Surv. of Mich., Annual Report for 1901, pp. 217, 218.
[5] Twelfth Rept. Mich. Acad. Sci., 1910, pp. 47-50. Also *idem*, Thirteenth Rept., pp. 87-96.

and strong artesian wells as the 'James Swan well' on Grosse Isle[1], is not especially favourable to a sharp anticlinal structure, although, of course, it does not necessarily disprove it. Moreover, the presence of Sylvania sandstone on certain islands in the Detroit river, and even in a portion of the bed of the stream, seems to indicate that the formation crosses at that point (Bois Blanc island). This might be the case even with an anticlinal structure to those beds, provided the axis is plunging to the northward. The comparatively gentle southward dip of the rocks in the 'dry cut' may simply indicate a local sag in an otherwise northerly plunging anticline. It is hardly probable that the driller can determine, with any degree of certainty, the dip of strata which are under a considerable depth of water and being cut by an ordinary churn drill; hence the structure over much of the river bottom must remain in obscurity.

So far as the fauna is concerned, the lowest beds cut by the Livingston Channel carry forms which are certainly more nearly related to the Onondaga fauna than those forms which occur in the Anderdon limestone lying immediately below the Onondaga in the Amherstburg quarries. The upper beds of the cut, 75 feet above the lowest rocks exposed during the work on the channel, carry the usual Monroe fauna which has always been considered typically upper Silurian, and a considerable portion of which has been found above the Sylvania sandstone at Silica, Ohio. From the limited investigation which the Canadian and adjacent Michigan outcrops allow, it is scarcely possible to make a satisfactory stratigraphic study of the Monroe. It will be necessary, therefore, to look to the state of Ohio, which is traversed from north to south by outcrops of these beds, for more satisfactory results.

The Devonian Formations.

In Huron and Bruce counties, where there is a great mass of Devonian limestones, the investigations of the past season have practically demonstrated that much of this deposit does not belong in the Onondaga to which it has formerly been referred. This was suspected after a study of the material obtained on previous trips. A visit to Alpena, Michigan, and a few days collecting in the Alpena limestone (middle Hamilton) of that vicinity, revealed the same fauna in it as that which occurs in the Stromatoporoid reefs at the falls of the Teeswater.

[1] Fuller, Myron L., Board of Geol. Surv. of Mich., Annual Report for 1904, pp. 19, 20.

GEOLOGY OF LAKE SIMCOE AREA, ONTARIO: BEAVERTON, SUTTON AND BARRIE SHEETS

(*W. A. Johnston*)

Introduction.

The field work of the past season was a continuation of the topographical and geological mapping of a portion of Lake Simcoe district, Ontario, on a scale of 1:62,500 or nearly 1 mile to 1 inch. An area of about 1275 square miles has now been mapped on this scale. Topographical relief is shown on the maps by contours at intervals of 20 feet. Intermediate contours, or 10 foot contours, are also used occasionally, for the purpose of showing small features of special significance.

Field work lasted from May 8 until November 26, in which work R. L. Junkin and C. H. Freeman assisted and rendered efficient service.

The first week in July was spent by the writer in company with P. E. Raymond, in an examination of some of the sections of the limestones of the Trenton and Black River groups, in the district lying between Prince Edward county and Lake Simcoe district. Small collections of fossils were made at a few localities in the Beaverton and Sutton areas. These fossils have been determined by Mr. Raymond and are referred to later in the report.

LOCATION AND AREA

The topographical field work of the past season consisted chiefly of the sketching of the Beaverton, Sutton, and Barrie map-areas, all of which were completed. The Beaverton map-area is bounded by latitudes 44° 15′ and 44° 30′ and longitudes 79° 00′ and 79° 15′ and includes a land area of about 175 square miles. The Sutton map-area is bounded by latitudes 44° 15′ and 44° 30′ and longitudes 79° 15′ and 79° 30′ and includes a land area of about 70 square miles. The Barrie map-area is bounded by latitudes 44° 15′ and 44° 30′ and longitudes 79° 30′ and 79° 45′ and includes a land area of about 180 square miles.

GENERAL CHARACTER OF THE DISTRICT

Within the limits of the Beaverton area the average relief is small, generally not exceeding 50 feet. The highest point is in the extreme southeast corner where drift hills rise to a height of about 350 feet above Lake Simcoe, the summer level of which is nearly 719 feet above mean sea-level. Throughout the northern and central portions of the area the surface deposits are thin, and nearly flat-lying limestones of Trenton age are often well exposed and form a rock divide between the waters of Lake Simcoe on the west side and the waters of the Trent valley on the east. The limestones dip slightly towards the southwest at an average rate of about 20 feet per mile. The most southerly exposure of solid rock seen in the area is in the bed of a brook at Pefferlaw village where a section of a few feet shows fossiliferous beds of the upper portion of the Trenton limestone. Throughout the southeastern portion of the area the surface deposits have considerable thickness and generally take the form of gently undulating till plains. This character of the surface, however, is frequently varied by imperfect drumlin forms and long, narrow, esker-like ridges. The southwestern portion of the area is characterized by nearly flat plains of sandy clay, which have an altitude of

about 50 feet above Lake Simcoe and lie below the Algonquin beach, a raised shore-line of one of the predecessors of the Great Lakes.

In the Sutton map-area the only known exposures of solid rock are on Georgina island in Lake Simcoe. On the northeastern side of the island a section at the water's edge shows about 25 feet of the upper portion of the Trenton limestone and over a considerable portion of the island the limestone is frequently exposed at the surface. The average relief in the area is small, and nearly flat sandy clay plains are a conspicuous feature in the southern portion. A few drift hills rise to a height of about 160 feet above Lake Simcoe, which is the maximum relief in the area.

Within the limits of the Barrie map-area no exposures of solid rocks are known to occur and the surface deposits over the greater part of the area have considerable thickness. The area is, roughly speaking, divided into two parts by Kempenfeldt bay, a long arm of Lake Simcoe, and by a broad, flat-bottomed valley extending westward for a number of miles from the head of the bay. The general altitude of the floor of the valley is about 50 feet above Lake Simcoe and drift hills rise steeply on either side to a height of from 200 to 300 feet above the lake. A boring made in the bottom of the valley near the town of Barrie showed the surface deposits to have a thickness of 335 feet below the level of Lake Simcoe. Lateral stream valleys show no exposures of solid rock and well borings made on the sides of the valley have shown the absence of rock to a depth of over 100 feet, so that at some points in the area, it is possible that the surface deposits have a maximum thickness of at least 500 feet. It is possible, however, that the sides of the valley are bordered by buried rock escarpments which would lessen the thickness of the drift, but no borings have been made deep enough to determine whether this is the case or not.

Southward from this valley and occupying the southwestern portion of the area is a comparatively high mesa-like upland, the surface of which has the general character of a slightly undulating, nearly flat till plain. The southeastern part of the area has more relief and is characterized by imperfect drumlin forms and gravel ridges. The two portions are separated by a broad valley extending southward from Kempenfeldt bay. In the northern portion of the area another broad, flat bottomed valley, bordered by high steep banks and similar to the valley at the head of Kempenfeldt bay, extends westward. This valley heads a few miles northeast of Little lake, which lies in the valley, about 2 miles north of the town of Barrie, and is separated from the Kempenfeldt Bay valley by high drift ridges. The flat-bottomed character of these valleys is evidently due to deposition in a body of water. This is shown by the character of the filling, which is mostly stratified sand and gravel, by the fact that the general surface of the floor of the valleys is very near the level of the Algonquin beach, which is well marked in the district by beach ridges, spits, etc., and by stream grading to the Algonquin level.

Throughout the area, below the level of the Algonquin beach, which in the southern portion of the area is about 55 feet above Lake Simcoe and in the northern portion rises to nearly 100 feet above the lake, sand and gravel plains and boulder-strewn terraces are conspicuous features. In the northeastern portion of the area the country rises gradually and, 4 or 5 miles back from the lake, reaches an elevation of 300 feet above the lake. The general surface is a gently undulating till plain, but gravel ridges having a northeast and southwest trend are numerous, and occasionally imperfect drumlin forms occur. In the northwestern part of the area, flat-topped uplands rising from 100 to 200 feet above the valleys are marked features. The highest points reached in the area are in the northwestern portion, about 1 mile north of the village of Dalston, where drift hills rise to an altitude of nearly 400 feet above Lake Simcoe. The lowest point is in the valley

of Willow creek which drains Little Lake valley. The elevation of the bed of the creek at the western border of the area is nearly 100 feet below the level of Lake Simcoe, so that the maximum relief within the limits of the Barrie area is about 500 feet.

Well borings which have penetrated the surface deposits at a few localities in the district show that the underlying rock is the Trenton limestone and it is probable that the whole of the Barrie and Sutton areas are underlain by this formation. At the town of Barrie, the underlying limestones which belong to the lower portion of the Trenton and to the underlying Black River groups, were found to have a thickness of only 200 feet above the Pre-Cambrian granites, etc. In the southern portion of the Sutton area nearly the whole of the Trenton limestone underlies the surface deposits. In this locality the limestones of the Trenton and Black River groups have an estimated maximum thickness of 550 feet.

General Geology.

Table of Formations

Recent.	Humus, sand dunes, marls, etc.
Pleistocene.	Raised beaches, fluviatile and lacustrine sands, gravels, and clays.
	Glacial clays, boulder clays and sands: fluvio-glacial sands and gravels.
	Interglacial sands, gravels, and clays.
	Boulder clays.
Ordovician.	
Trenton limestone (group)	*Hormotoma* and *Rafinesquina deltoidea* beds.
	Prasopora beds.
	Crinoid beds.
	Dalmanella beds.

DESCRIPTION OF FORMATIONS

Ordovician

Trenton Limestone (Group)

Hormotoma and Rafinesquina Deltoidea Beds.—The highest beds of the limestones of the Trenton group seen in the district are best exposed in the bed of a brook at the village of Pefferlaw, in the township of Georgina, Ontario, and on Georgina island in Lake Simcoe. The beds exposed at Pefferlaw consist of about 4 feet of light grey, rubbly limestone weathering to an ash grey or creamy colour, and are probably somewhat higher in the series than those on Georgina island. At the northwestern corner of the island, where a local fold in the limestone occurs, about 10 feet of light grey, rubbly limestone in thick beds are exposed. The limestone weathers to a soft, clayey mass and is rich in fossils. On the northeastern side of the island a section of about 25 feet at the water's edge shows the rubbly beds to be underlain by thinly and irregularly bedded, hard, greyish brown limestone, somewhat barren of fossils. The following fossils collected by the writer from these localities have been determined by Mr. P. E. Raymond:—

Northwest corner of Georgina island, Lake Simcoe.—

Streptelasma corniculum, Hall.
Plectorthis plicatella, Hall.

Platystrophia lynx, (Eichwald).
Plectambonites sericeus, (Sowerby).
Sinuites, sp. ind.
Bucania, sp. ind.
Holopea, cf. *H. excelsa*, Winchell and Scofield.
Lingula cobourgensis, Billings.
Dalmanella rogata, Sardeson.
Strophomena humerosa, Raymond.
Trochonema umbilicatum, Hall.
Salpingostoma, sp. ind.

Bed of brook, Pefferlaw village, Ontario.—

Climacograptus sp. ind.
Streptelasma corniculum, Hall.
Lingula cobourgensis, Billings.
Dalmanella rogata, Sardeson.
Plectambonites sericeus, (Sowerby).
Rafinesquina alternata, (Emmons).
R. deltoidea, (Conrad).
Strophomena humerosa, Raymond.
Hebertella bellarugosa, (Conrad).
Rhynchotrema increbescens, Hall.
Cyclospira bisulcata, (Emmons).
Trochonema umbilicatum, Hall.
Hormotoma trentonensis, Ulrich and Scofield.
Cyclonema bilex, (Conrad).
Illænus americanus, Billings.
Isotelus gigas, Decay.
Cheirurus sp. ind.

Regarding the occurrence of these fossils, Mr. Raymond states: 'The faunas of the above localities are plainly upper Trenton, and are to be correlated with the upper Trenton strata on Division street and at Dow's lake at Ottawa, and with the strata at the top of the bluffs at Picton, Ont.' These beds which are characterized by *Hormotoma trentonensis* and *Rafinesquina deltoidea* probably underlie the southern portions of the Beaverton and Sutton areas, but good exposures are rare and little opportunity is afforded to determine their thickness. As calculated from the dip they have an estimated maximum thickness in the district of 150 feet. It is possible that the lower portion of these strata, which consists, principally of more thinly-bedded, greyish brown, hard limestone, has a sufficiently distinct fauna to form a sub-zone, but enough fossil evidence has not been obtained to determine this.

Prasopora Beds.—The strata, which are characterized by a great abundance of fossils of the genus *Prasopora*, underlie the greater part of the northern portion of the Beaverton area and are often exposed at the surface, but good sections are rarely seen. These beds, which consist, for the most part, of thinly-bedded, bluish grey limestone, are similar both lithologically and faunally to the beds described in the Summary Report for last year as occurring at Fenelon Falls, near Kirkfield, and 2 miles south of Brechin. The following fossils, determined by Raymond, were collected from the upper and middle portions of the *Prasopora* beds which have an estimated maximum thickness in the district of nearly 200 feet. The upper portion of this zone from which the fossils of the first of the following lists were obtained consists of somewhat thicker bedded, hard, grey limestone in which fossils of the genus *Prasopora* are not so abundant:—

Lot 12, Con. I, Eldon township, Ontario.—

Dalmanella rogata, Sardeson.
Plectambonites sericeus (Sowerby).
Clitambonites americanus (Whitfield).
Rafinesquina sp. ind.
Rhynchotrema increbescens, Hall.
Agelacrinites billingsi, Chapman.

Lot 15, Con. III, Eldon township, Ontario.—

Prasopora simulatrix, Ulrich.
Dinorthis meedsi, Winchell and Schuchert.
D. iphigenia, Billings.
Platystrophia lynx, (Eichwald).
Rafinesquina alternata, (Emmons).
Rhynchotrema increbescens, Hall.
Hormotoma gracilis, (Hall).
Calymene senaria, Conrad.

Lot 2, Con. VIII, Thorah township, Ontario.—

Prasopora simulatrix, Ulrich.
Orbiculoidea sp. ind.
Platystrophia lynx, (Eichwald).
Rafinesquina alternata, (Emmons.)
Rhynchotrema increbescens, Hall.
Raphistomena rugata, Ulrich and Scofield.
Eotomaria, sp. ind.
Lophospira bicincta, (Hall).
Ceraurus pleurexanthemus, Green.
Calymene senaria, Conrad.
Isotelus gigas, Dekay.

Regarding these fossils Raymond states: 'The strata at these three localities are evidently in the Prasopora zone. The presence of Agelacrinites in the first list indicates that the strata at that locality are some distance above the base of the Prasopora zone.'

Crinoid and Dalmanella Beds.—The Crinoid and Dalmanella beds, which underlie the Prasopora beds and form the two lowest zones of the Trenton, were described in the Summary Report for last year. These beds have a combined thickness of about 85 feet.

Considering the mapping qualities of the different faunal zones of the Trenton in the district, it appears that the three lowest zones, including the Dalmanella, Crinoid, and Prasopora beds, to which the group name of 'Kirkfield limestone' was given by the writer in the Summary Report for 1910, can be mapped as a group, apart from the upper portion of the Trenton, but can hardly be mapped separately on account of the limited areal distribution of the two lowest zones and the general absence of any definite dividing line between them.

As stated above, the estimated maximum thickness of the limestones of the Trenton and Black River groups in the district is 550 feet, of which 440 feet belong to the Trenton and 110 feet to the Black River group. The latter includes at the base a small thickness of red and green shales and coarse sandstone or arkose resting on the Pre-Cambrian granite, etc. These beds are sometimes absent

but occasionally have a maximum thickness of 50 feet. The average thickness appears to be about 20 feet. In the districts lying to the south and west of Lake Simcoe district, where the total thickness of the limestone of the Trenton and Black River group is developed, well borings have shown the beds to be nearly 600 feet thick. At Whitby, Ontario, they were found to be 608 feet in thickness, at Toronto, 605, and at Collingwood, where the top of the well was about 50 feet below the top of the Trenton, 543 feet. Hence it is probable that the highest beds of the Trenton limestone found in the Lake Simcoe district are from 50 to 100 feet below the top of the Trenton.

Pleistocene.

Numerous sections in the surface deposits or drift of the district show two till or boulder clay sheets separated by stratified sands, gravels, and clays. The uppermost or last till sheet consists of two distinct portions, an upper part, often with a well-bedded character and composed of a loose sandy till, and a lower portion consisting of a more compact sandy clay till with little or no trace of stratification.

Associated with the upper portion of the last till sheet, and generally crowning the summits of hills and ridges at various altitudes up to a hundred feet or more above the level of the Algonquin beach, are well stratified deposits of sands and gravels which often bear a semblance to beach ridges. Their mode of origin is not clear, but they do not appear to be referable to wave-built features, as they are, generally, not horizontal, and although they are frequently strongly developed there is often no trace of wave action on adjacent slopes and at accordant levels, where the surface material and exposure was favourable for the record of wave-built features. These stratified sand and gravel deposits generally take the form of smoothly rounded, elongated ridges and appear to have suffered little erosion since they were formed. The elongation is nearly always in the direction of ice movement of the last ice sheet, so that it seems probable that they are associated with the last movement of the ice sheet in the district and are possibly of the nature of flattened kames.

Over a considerable part of the district the till of the lower portion of the last till sheet merely forms a thin veneer which conforms to the contour of the underlying stratified sands, gravels, and clays. These interglacial beds are of considerable thickness and appear to have suffered a long period of erosion prior to the deposition of the last till sheet, during which time broad valleys were carved in the earlier deposits. This is well seen in the Barrie area where a number of remarkably broad and deep valleys in the drift occur. The upper till is frequently seen in small sections on the sides of the valleys forming a thin veneer over the underlying stratified sands and gravels, while in the bottom of the valleys, sections show the upper till resting directly on the lower till.

The till of the lower till sheet is generally only exposed in the beds of streams, where it is seen to be composed of hard, compact, sandy clay till without stratification, containing numerous well polished and striated pebbles and boulders. This till withstands erosion remarkably well and where trenched by streams is sometimes seen to stand up in vertical section or to form ledges causing rapids. Some of the best sections of the lower till seen in the district are in the bed of Lovers creek, about one mile east of Allandale.

Possibility of the Occurrence of Gas or Oil in the District.

During the past summer a well boring was made at the town of Barrie in search of natural gas or oil. The boring was started on the flat just west of the

town at a height of 40 feet above Lake Simcoe, and passed through 375 feet of surface deposits consisting of sand, gravel, clay and boulder clay, at which point the Trenton limestone was reached. The boring continued through nearly 200 feet of the limestones of the Trenton and Black River groups to the Pre-Cambrian. At the base and resting on the Pre-Cambrian granite or gneiss there were about 20 feet of coarse sandstone or arkose and interbedded with the sandstone a few feet of reddish and bluish shales. No gas or oil was noted.

Regarding the possibility of obtaining natural gas or oil in the district by boring it may be stated that a great many borings have been made into and through the limestones of the Trenton and Black River groups in Ontario, but, so for as known, gas or oil has not as yet been found in commercial quantities in these limestones in Ontario. In a number of instances natural gas, with a considerable initial pressure, has been struck in the Trenton but the pressure soon so lowered as to make the production of little commercial value. Oil in small quantities has also been reported from the Trenton in a few localities in Ontario. These occurrences appear to be confined for the most part to the upper 200 feet of the Trenton, but in a few instances gas has been struck lower down in the formation and even in the coarse sandstone or arkose at the base of the series. Where the whole of the series is developed in adjacent districts, the limestones of the Trenton and Black River groups have a thickness of about 600 feet. Of this thickness the upper 200 feet are somewhat porous, but the lower portion is composed, for the most part, of fine-grained, compact limestone unsuited for the storage of gas or oil. In the vicinity of the town of Barrie, only the lower 200 feet of the limestone series underlie the surface deposits. Westward from Barrie in the valley of Nottawasaga river the surface deposits are known to have a thickness at some points of at least 300 feet, and, as the surface of the ground is over 100 feet lower than at Barrie, it is probable that the underlying limestones have a still less thickness. In the southern portion of the district the limestones are much thicker and conditions are hence more favourable, but on the whole, while it cannot be said that gas or oil will not be found in the district, the probabilities seem to be against their occurrence in commercial quantities.

GEOLOGY OF ONAPING SHEET, ONTARIO.

(*W. H. Collins*).

Introduction.

GENERAL STATEMENT.

Between May 5 and May 23, 1912, the writer reviewed the geology along the National Transcontinental railway between Winnipeg and Lake Nipigon. The remainder of the field season was occupied in continuing a geological reconnaissance of Onaping map-area, a rectangular area 72 miles long by 48 miles wide lying 30 miles north of Sudbury. This work was first undertaken in 1905 by Mr. W. J. Wilson but was discontinued after the first season. A few years later, however,

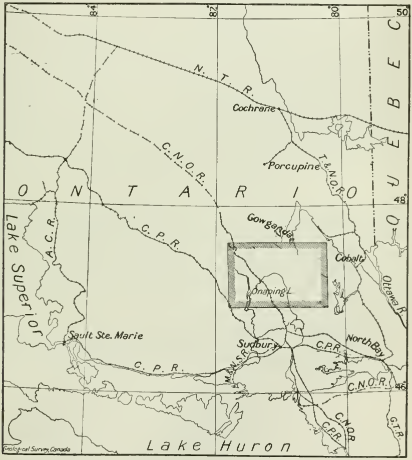

Fig. 9.—Index showing position of Onaping map-area.

the wide-spread prospecting activity excited by the discoveries of silver at Cobalt and Gowganda gave rise to an unusual demand for information regarding Onaping map-area, in which also the silver-bearing diabase formation occurs; so, to satisfy this demand, the present investigation was begun in 1910.

Besides the areal work in Onaping map-area a strip of country extending from there to the Sudbury area mapped in 1905 by Professor A. P. Coleman was also examined and the relationships of the Huronian formations in these two areas thus ascertained. Two brief visits were also made to Moose Mountain iron mine at Sellwood, where preparations are under way for mining and concentrating magnetite ore containing only 36 per cent of iron.

A large share of the work accomplished this year is due to the co-operation of Messrs. J. J. O'Neill and J. R. Marshall and their assistants, Messrs. L. C. Prittie, A. C. Hazen, and W. K. Thompson. My own work was advanced by the able assistance of Mr. T. L. Tanton. Particular acknowledgments are due also to Professor A. P. Coleman for assistance in recognizing the Huronian succession at Sudbury and to Mr. F. A. Jordan, manager of Moose Mountain iron mine, for assistance and information relative to Moose Mountain mine and iron range.

MEANS OF ACCESS.

The main line of the Canadian Pacific railway crosses the southwestern corner of Onaping map-area, and access therefrom to the adjacent country is further facilitated by wagon roads which have been built by lumbering companies for hauling supplies from the railway to the nearest navigable waterways. The eastern part of the area can be reached with least difficulty by way of the Timiskaming and Northern Ontario railway and Lake Timagami. Small steamers and gasoline boats ply between Timagami station and all parts of the lake. But the Canadian Northern Ontario railway, now under construction between Sudbury and Port Arthur, is the most important means of ingress. This line was extended northwestward across the area during 1912 and a regular train service is now in operation over it.

SUMMARY AND CONCLUSIONS

The principal conclusions expressed in the succeeding part of this report are:—

(1.) The Ramsay Lake conglomerate at Sudbury is equivalent to the conglomerate formation of the Cobalt series and is long antedated by another important sedimentary series (Sudbury series) which suffered diastrophism, batholithic intrusion, and extensive erosion before Cobalt-series deposition began.

(2.) 'Keewatin' volcanic activity probably persisted beyond the invasion of the pre-Cobalt granite-gneiss, and the schist complex usually called Keewatin sometimes includes these later formations. Hence the name Keewatin is not always applicable to the complex as a whole.

(3.) The Keweenawan or post-Keweenawan diabasic intrusions in different parts of the region differ in composition, and with these differences is perhaps related a corresponding diversity in the mineral deposits genetically associated with them.

General Geology.

GENERAL STATEMENT

The solid rocks underlying Onaping map area are entirely Pre-Cambrian and are separable into four major divisions. A schistose complex of dominantly volcanic origin constitutes, at least in part, the oldest division. This complex, usually called the Keewatin, occurs in irregular areas which are surrounded and intruded at all observed points by the batholithic granite-gneiss, which forms the second great division. At the close of this batholithic invasion the older volcanic complex had been folded and metamorphosed to an extent implying

mountain building. The schists and the granite-gneiss were then eroded to an uneven plain not greatly different from the present surface of the country and upon this surface was deposited a series of Huronian sediments (Cobalt-Lorrain group). In Keweenawan or post-Keweenawan time all these formations were intruded by dykes and sills of various diabasic materials. The present peneplanated surface of these Pre-Cambrian rocks is glaciated and thinly covered by Pleistocene boulder clay, sand, and gravel.

Table of Formations

Pleistocene	Boulder clay, gravel, and sand.
Great unconformity.	
Keweenawan or post-Keweenawan	Intrusive dykes and sills of quartz-diabase, and quartz-norite; later dykes of olivine-diabase.
Cobalt-Lorrain	Conglomerate, greywacke, banded greywacke, limestone, and quartzite (Cobalt-Lorrain group.)
Great unconformity.	
Pre-Cobalt batholithic intrusives	Gneissoid granites with aplitic and pegmatitic derivatives; inclusions of older rocks and magmatic assimilation products.
Intrusive contact.	
Pre-Cobalt schist group	Volcanic and intrusive igneous rocks; conglomerate, arkose, and slate; iron formation.

DESCRIPTION OF FORMATIONS

Pre-Cobalt Schist Group.

The ancient schist group, more widely known under the name Keewatin than by its present designation, is much too complex to be separated into its component formations by the reconnaissance methods employed for mapping most of Onaping area. It has been treated as a unit everywhere except in a small gold-bearing area near West Shiningtree lake where the economic conditions justified more detailed work. Even there only an incomplete part of the geological record contained in this schist complex was deciphered, but this fragment of early Pre-Cambrian geological history is sufficiently interesting to deserve the following outline:—

(1). The older formations—apparently all igneous intrusives and extrusives of dominantly basic composition—were left undifferentiated. They have been greatly disturbed, more or less changed to chloritic schists, decomposed, and recrystallized to hornblende schist near their contacts with the intrusive granite-gneiss.

(2). The oldest formation resolved from this complex is a volcanic flow and associated coarse tuff of hornblende porphyrite.

(3). This eruption was followed by another of rhyolite and rhyolite tuff.

(4). The rhyolite tuff grades insensibly upward into a conglomerate, the pebbles in which consist almost altogether of this rhyolite and hornblende porphyrite—the immediately subjacent formations. The conglomerate is succeeded conformably by an arkose-like formation composed of still finer rhyolite fragments and this, in turn, passes into a well-stratified slate in which there are local banded iron formation phases. Under the microscope this slate proves to be a consolidated volcanic mud. These sediments occupy a known area of 3 square miles and are at least 100 feet thick.

(5). The sediments are cut by dykes of a rock of intermediate composition which occurs elsewhere in larger bodies of undetermined character.

(6.) Up to this point all the formations have been folded, sheared, and otherwise greatly disturbed, but they are overlain by much more gently folded formations. The first of these is a flow of ellipsoidal andesite, so little disturbed that the original volcanic structures are perfectly preserved.

(7). The andesite is cut by dykes of rhyolite which elsewhere occurs in larger masses.

(8). Quartz veins, some of which are auriferous, intersect the rhyolite, andesite, and probably all of the older formations. They probably represent more than one period of vein formation.

(9). Both andesite and rhyolite are intruded by dyke-like bodies of porphyritic granodiorite.

(10). The only younger rocks in the locality are dykes of Keweenawan or post-Keweenawan quartz-diabase and olivine-diabase, which intersect even the porphyritic granodiorite.

The relationships of the schist group as just stated, appear to differ in two important respects from such as are generally recorded for the group in the region at large.

(1). At various places in northern Ontario and Quebec sedimentary formations have been discovered among the ancient schists, but in most cases where a detailed examination has been made, these sediments have been separated from an igneous 'Keewatin' portion on the ground of unconformity. Banded iron formation is the only sedimentary formation which has been allowed to remain in the Keewatin. The relationship of the sediments in the present case appears to be different. No unconformity has been observed at the base of the conglomerate, which grades into the underlying rhyolite tuff. Also the conglomerate and arkose have been derived almost exclusively from water-worn rhyolite and porphyrite tuffs, a single granite pebble being the only observed evidence of more extensive erosion and transportation. The sedimentary series appears to be of local importance only and to be in conformity or at most, faint unconformity with the subjacent volcanic tuffs. There seems to be no good reason, therefore, for separating these sediments in West Shiningtree district from the schist complex on the ground that they mark any important period of time.

(2). Wherever the schist complex has been observed in contact with granite gneiss in this or adjacent districts it is contact-metamorphosed and evidently the older of the two. The batholithic intrusion of the granite-gneiss must also have been intimately related to the movements which folded and sheared the schists, for the schistosity in the latter exhibits a distinct parallelism with the granite-gneiss contacts. It has been generally assumed from these two relationships that all the component formations of the schist complex were older than the granite-gneiss. But the ellipsoidal andesite flow in the West Shiningtree schist area is gently folded and apparently escaped the intense deformation to which older formations in the same complex were subjected. A still more pronounced example of this was observed in 1910 near Shiningtree lake where a comparatively horizontal flow of rhyolite rests upon the upturned edges of the older schists, clearly implying that it was not extruded until long after the disturbance which was accompanied by the batholithic intrusions has ceased. Apparently, therefore, some of the formations comprising the schist complex in this locality are younger than the intrusive granite-gneiss, and the name Keewatin as defined by the Special Committee for the Lake Superior Region is not applicable to the complex as a whole. It is not unlikely that, if other parts of the schist complex were examined in detail, the name Keewatin, thus used, would be found to be more widely inapplicable to it.

Pre-Cobalt Batholithic Intrusives

The granitic rocks in Onaping map area are all older than the Cobalt series. Those in Sudbury district intrude an older sedimentary series, but whether all or only a part of them bear this relation cannot be determined. Neither are the relations of the Sudbury sedimentary series to those in any of the districts examined by the Special Committee known. Consequently the present designation is used instead of the name Laurentian.

Granite-gneisses occupy a continuous area of 1,300 square miles in the western part of the map-area and are also exposed in numerous smaller areas where the overlying mantle of Cobalt series sediments has been eroded.

Cobalt-Lorrain Group

The Cobalt-Lorrain group is unusually well developed in the southeastern part of the map-area and afforded unusual opportunities last summer for obtaining a complete succession, which hitherto has not been described. It was found to consist of two conformable but essentially unlike parts: a lower portion consisting of conglomerate, greywacke, either massive or delicately stratified and often with quartzitic phases, and a small amount of limestone, all except the limestone being dark grey in colour (Cobalt series); an upper portion of pale, whitish colour and consisting of feldspathic quartzite with conglomeratic and chert-like variations (Lorrain series).

The members of the Cobalt series are not constant in their order of succession, but in practically all cases conglomerate, from a few feet to several hundred feet in thickness, lies at the bottom. This is succeeded in somewhat variable order by massive or delicately banded greywacke, and impure quartzite, but the uppermost formation wherever observed is stratified greywacke. This stratified greywacke contains a bed not over 10 feet in thickness of grey limestone finely interlaminated with thin sandy layers. The general character of the Cobalt series indicates it to be essentially a terrestrial deposit, its stratified portions representing deposition in bodies of water of small extent and duration.

The thick quartzite formation constituting the Lorrain series consists chiefly of massive feldspathic quartzite, the feldspar fragments in which sometimes show cleavage faces a half inch across. Locally this grades into a very pure white quartzite, into impure finely stratified quartzite so fine textured as to be indistinguishable from chert, or into thin conglomerate beds. It is abundantly ripple-marked and cross-bedded and has the characteristics of a sub-aqueous deposit.

At a few points in the northern part of the map-area and in Gowganda and Cobalt districts, this quartzite has been found lying unconformably upon the Cobalt series. Sometimes there is a thin basal conglomerate or breccia containing fragments of the underlying greywacke, sometimes only an irregular contact surface and in a few instances the quartzite reposes directly upon the older granite-gneiss. All of these indicate an unconformity at the base of the Lorrain quartzite. On the strength of this unconformity the quartzite has been regarded as distinct from the Cobalt series and called Lorrain[1]. But there are other localities known in each of these districts where the relations indicate conformity. Also in the southern part of Onaping map-area, where, as already remarked, the base of the quartzite has been repeatedly observed, it is always conformable with the underlying stratified greywacke. The change from greywacke to quartzite usually begins with the appearance in the greywacke of thin quartzite layers which, within 40 feet in an

[1] Miller, W. G.; Rep. Bureau of Mines, Ontario, vol. XIV, part II, 1905.

upward direction, grow thicker and more numerous until a continuous quartzite formation results. The unconformities which have been recorded are, therefore, discontinuous and either due to overlap or only interformational in importance. The existence of conformable relations not far away from each of the localities where unconformity has been found favours the latter conclusion. But, while the unconformity is not a continuous one, and might seem to disqualify the names Cobalt and Lorrain, the essentially different manner of deposition of the sediments in question does seem to justify a retention of these names, at least until the rocks are better known.

For Onaping map-area at least there is little unconformity and the succession may be summarily described as follows:—

Cobalt-Lorrain group.	Quartzite	1000 + feet thick.
	Faint local unconformity.	
	Stratified greywacke. Greywacke, banded greywacke, and limestone in somewhat variable succession. Conglomerate.	0 to 1000 + feet thick.

Keweenawan or Post-Keweenawan.

The diabasic rocks which, in the form of sills and dykes, intrude the Cobalt-Lorrain and older rocks are probably Keweenawan or slightly later in age. Although they are all sufficiently continuous and alike in composition and mode of intrusion to indicate a common magmatic origin, the intrusives in one part of the region may differ importantly from those in another part. Thus all the known dykes and sills in the northern part of the area, with the exception of a few younger olivine-diabase dykes, consist of quartz-diabase. They were intruded tranquilly, with little disturbance of the older formations, and are accompanied by vein deposits of silver, cobalt, nickel, and copper-bearing minerals. The diabase sills in Gowganda district are representative of this type. A second type occurs near the centre of the map-area. It is exemplified by a large sill of quartz-norite more closely allied to the Sudbury nickel eruptive petrologically than to the silver-bearing quartz-diabase, though no nickel deposits have been found in it. Probably a third type is represented by sills which occur at the southeast corner of the map-area, near Wanapitei lake. Unlike the silver-bearing quartz-diabase sills or the quartz-norite sill, these have been intruded with intense local disturbance and development of crush breccias in the older formations. Only one thin section of the rock composing them has been examined, but this shows pronounced differences from both the typical quartz-diabase and the quartz-norite. The primary ferro-magnesian minerals are hornblende and biotite instead of pyroxene, and quartz is remarkably abundant. Moreover, these sills and the adjacent rocks are intersected by veins carrying free gold in a gangue of quartz and iron-magnesium carbonate.

The mineral deposits which accompany these different phases of the Keweenawan intrusives are unlike in most respects, nevertheless they possess certain features which may be significant of their related derivation. Gold is not confined to Wanapitei district but occurs in the Sudbury ores; also in the silver-cobalt ores of the Mann mine at Gowganda, and in veins in quartz-diabase on Lake Abitibi. Silver, nickel, and copper also are found in the Sudbury ores as well as in the Cobalt type though in very different proportions.

The facts concerning the Keweenawan intrusions are neither abundant nor yet well demonstrated but they at least suggest that the diabasic rocks of which they consist include several slightly different petrological types, each of which is more or less distinct from the others in its geographical distribution and is accom-

panied by its own peculiar type of mineral deposit. Possibly, herein lies the reason why silver-cobalt ore deposits have not been found in association with the diabase sills west of Lake Timagami.

Pleistocene.

The Pleistocene drift which covers the Pre-Cambrian rocks to depths ranging from 0 to 100 feet, consists of boulder clay and outwash deposits of sand and gravel. Lacustrine stratified clays do not occur in this area.

Correlation.

The Pre-Cambrian succession in Sudbury district was announced by A. P. Coleman in 1905[1]. According to this classification, which is summarized in column 1 of the table of formations, page 309, a series of sediments and associated igneous rocks (McKim greywacke, Copper Cliff arkose, and Huronian eruptives) are the oldest rocks in the district. They are folded closely and intruded by batholiths of granitoid gneiss. They are also overlain unconformably by a younger conglomerate (Ramsay Lake conglomerate). There is a third, still younger series (Trout Lake conglomerate, Onaping tuff, Onwatin slate, and Chelmsford sandstone) regarded as Animikie (Upper Huronian), which is, however, intruded and so completely isolated from the older formations by the great laccolithic body of norite with which the ore deposits of the district are connected, that its relations to these formations cannot be determined satisfactorily. The norite, together with dykes and other intrusive bodies of diabase and granite, are regarded as Keweenawan in age.

Barlow[2] believes that the oldest sediments mentioned by Coleman are antedated by a schist complex of Lower Huronian (Keewatin) age. There are also granite pebbles in the Copper Cliff arkose which imply an older granite formation. These two members have been added, in column 1 (p. 309) to Coleman's classification.

In the same year that Coleman's report appeared, the Pre-Cambrian succession in Cobalt district was defined by W. G. Miller[3] as shown in column 2 (p. 309). A schistose complex of volcanics and minor sedimentary material constitutes the oldest group of rocks (Keewatin). This is intruded by granite-gneiss (Laurentian), while upon the deeply eroded surface of both schists and granite-gneiss reposes a succession of gently folded Huronian sediments (Cobalt series and Lorrain). All these formations are intruded by dykes and sills of diabase. Lately Dr. Miller has described a sedimentary series in Cobalt district, which is older than the Cobalt series, and is intruded by granite and to which he has applied the name, Timiskaming series[4].

The economic importance of these districts admitted of such careful and accurate work being done in each that the conclusions remain at the present time essentially unchanged, yet they are sufficiently unlike to imply that a complete Pre-Cambrian succession does not exist in either district. Since 1908 the writer has been at work in the interval between Cobalt and Sudbury districts and this year finally connected them by examing a narrow strip of country from the southern edge of Onaping map-area to the eastern edge of the Sudbury area mapped by

[1] The Sudbury Nickel Field, Report of Bureau of Mines, Ont., vol. XIV, part III.

[2] Reprint of a Report on the Nickel and Copper Deposits of Sudbury Mining Area: Geol. Surv. of Canada, No. 961.

[3] The Cobalt Nickel Arsenides and Silver Deposits of Timiskaming: Report of Bureau of Mines, Ontario, vol. XIV, part II.

[4] Notes on the Cobalt Area, Eng. and Min. Jour., vol. 92, p. 647.

Coleman. The sand plains south of Lake Wanapitei interfered somewhat with continuous geological observation along so narrow a strip, nevertheless the relationships determined are believed to be correct. Cobalt conglomerate was found resting unconformably upon the upturned edges of Copper Cliff arkose beds. Also the Cobalt conglomerate and Ramsay Lake conglomerate proved to be alike in lithological character and in their relationship to the Copper Cliff arkose and are, therefore, considered to be identical.

It is accordingly possible to obtain a more complete Pre-Cambrian succession for the region involved by combining in column III the facts recorded by Coleman, Miller, and Barlow. Certain modifications have been found necessary, however.

The name Sudbury series, lately adopted by Professor Coleman to include the McKim greywacke, Copper Cliff arkose, and contemporaneous volcanic rocks, is applied to these formations.

A practicable classification of the granitic rocks of the region is somewhat difficult. There are granite-gneisses in Sudbury district which intrude the Sudbury series and are, therefore, younger than it. And there are, or were, granites older than this series, for it contains granite pebbles. These pre- and post-Sudbury granites are probably not restricted to Sudbury district, but may occur in other parts of the region. Whether any given area of granite belongs to one division or other would be decided, naturally, by discovering its relationship to the Sudbury series or some equivalent series. But such a distinction appears to be a rather remote possibility, for these time-marking sedimentary formations are known only at long intervals apart. Perhaps more will be found, but those known at present are inadequate for the purpose of subdividing the granitic rocks. In many districts, and for some time to come, these granites must remain unsubdivided and hence some collective name, without definitely limited age significance, such as Pre-Cobalt or Pre-Huronian batholithic intrusives, is needed for such undifferentiated areas. When the need arises in this region special names can be coined for such granites as may be shown to be older or younger than the Sudbury series or its equivalent.

It is proposed also to suggest tentatively a return to the original usage of the term, Huronian, though not to apply it in this sense until further correlation thoroughly justifies such a usage. The work of Professor Coleman in the interval between Sudbury and the original Huronian area on Lake Huron has led him to the conclusion[1] that the Cobalt series at Sudbury is equivalent to a portion of the sedimentary formations on Lake Huron to which the name Huronian was first given. If this is the case, the Cobalt-Lorrain group becomes part of the Huronian.

It seems undesirable, however, to apply the age term Huronian to both Sudbury and Cobalt-Lorrain groups. Although estimated by Coleman to be 11,000 feet thick, the Sudbury series consists of coarsely clastic material and probably required no extraordinary length of time for its deposition. The Cobalt-Lorrain group is thinner and probably accumulated in less time. But the interval between these two series seems to have been extremely long, for during it the Sudbury series endured orotectic movements, granite batholiths were intruded, and the region was afterwards reduced to a peneplain. If the conditions of that time are at all comparable, say, to those that have obtained in the Rocky Mountain region since the Cambrian, then the time which elapsed in this interval of mountain-building and peneplanation must have been very much greater than that required for the deposition of either the Sudbury or Cobalt-Lorrain series. Hence to apply the common name Huronian to these series would obscure rather than call attention to the importance of the intervening time gap. It would fail also to emphasize the fact that the Sudbury series lies within or before the great period of Pre-Cambrian batholithic intrusion, while the Cobalt series belongs to a later quiescent period.

[1] Verbal communication.

For these reasons the base of the Huronian is located at the great unconformity between the Cobalt and Sudbury series. Its upper limit was defined long ago by Logan[1] as the base of the Palæozoic. The Huronian, therefore, would include the Cobalt-Lorrain, Animikie, and Keweenawan of column III, thus retaining nearly its original significance and recognizing structural and metamorphic similarities which naturally bind these formations together.

I.	II.	III.
Pleistocene.	Pleistocene.	Boulder clay, etc.
	Silurian (Niagara)	*Important unconformity.* Niagara.
Keweenawan { Latest granite dykes. Olivine diabase dykes. Granite. Sudbury nickel-bearing eruptive.	Post-Middle Huronian { Olivine diabase. Diabase.	*Important unconformity.* Diabasic intrusives.
Animikie { Chelmsford sandstone. Onwatin slate. Onaping tuff. Trout Lake conglomerate.		*Irruptive contact.* Chelmsford sandstone. Onwatin slate. Onaping tuff. Trout Lake conglomerate.
Huronian—Ramsay Lake conglomerate	Middle? Huronian. (Lorrain). Lower? Huronian. (Cobalt series).	Lorrain series. Cobalt series.
Laurentian granitoid gneiss.	Laurentian granite and gneiss (Lorrain granite).	*Great unconformity.* Granitic batholithic intrusives.
Huronian { Acid and basic eruptives. Copper Cliff arkose McKim greywacke.	Timiskaming series.	*Irruptive contact.* Sudbury series.
Granite pebbles in Copper Cliff arkoses		*Unconformity.* Granite intrusives.
Lower Huronian (Keewatin)	Keewatin-greenstones, porphyries, pseudo-conglomerate, etc.	Keewatin group.

Economic Geology.

GOLD.

West Shiningtree Area.

The geology of this area and the various gold occurrences known therein at the time were described in the Summary Report for 1911. A few other discov-

[1] Esquisse Geologique du Canada, Paris, 1855.

eries have been made since then, but, so far as the commercial future of the area is concerned, the only critical developments are those which have added information regarding the dimensions and average gold content of the more promising veins already known. The best of these veins have been stripped for from 200 to 550 feet along the surface, are from 12 to 40 inches wide, and dip nearly vertically. From what can be seen of these on hillsides and in exploration shafts they are practically undiminished in size at depths of 40 feet and probably have much greater depths. Certain broad exposures of quartz, which were hoped to be dimensionally similar to the Porcupine 'domes,' have proved in several instances, however, to be anticlinal parts of folded veins and are not continuous in depth. But while there are a number of gold-bearing veins quite large enough to encourage further development, their average contents of gold are either yet unknown to the writer or have proved disappointingly small.

There are four prospects deserving individual mention:—

Gosselin.—This property is situated on the northern boundary of Asquith township, not far east of West Shiningtree lake. An option of purchase was given in 1911 to a party of capitalists in Duluth, Minn., by the present owners and during the winter and spring of 1912 the more promising veins were stripped and sampled. An inclined shaft was also sunk 42 feet on one vein where gold had been found at the surface. The option was allowed to lapse in July, however, since when no further work has been done.

Jefferson.—This consists of one claim on the east side of Wasabika lake, in MacMurchy township. Three principal veins have been uncovered one of which extends in a north-south direction and crosses two others that strike east-west. The larger of the east-west veins is 30 inches in maximum width and is exposed for over 200 feet. Handsome specimens of free gold have been taken from it, but mineralization on the whole appears meagre.

Saville.—This claim adjoins the Jefferson property and is of the same general character and order of importance.

Bennett.—The Bennett claims lie on the east side of Montreal river, about a half mile southeast of the Jefferson and Saville claims. One vein has been stripped for 550 feet showing a width of 12 to 40 inches. In one of its broader parts a vertical shaft has been sunk in quartz to a depth of 40 feet. Free gold is visible at some half dozen points along the top of the vein and is stated to occur at intervals to the bottom of the shaft, but no average samples have been taken. Several smaller veins have also been exposed, one of which is folded, presenting a deceptively large apparent width where its overturned side is exposed.

Wanapitei District.

Crystal Mine:—The Crystal mine, situated on the east side of Wanapitei lake, on the portage leading to Mattagamishing lake, was once the most promising of a group of gold discoveries made in the vicinity of Wanapitei lake twenty years ago. Although actively mined for a period of years following 1892, it has been idle for the last three years; nor is there any immediate prospect of work being resumed. But while the mine is of no present commercial importance the geological relationships of its ore bodies are interesting.

The mine is located on a contact between banded greywacke and greenish arkose belonging to the Cobalt series and an intrusive mass of diabase similar in appearance to the other post-Cobalt-series diabases of the region. The Huronian beds in the neighbourhood dip at about 25° or less, but near the diabase they are more highly tilted, while the contact is often marked by crush breccia of both intruded and intruding materials. In the little hill which contains the mine workings, both diabase and sediments are intersected by half a dozen or more

quartz veins averaging less than a foot in width. These are composed of a gangue of quartz and light brown iron-magnesium carbonate (breunerite) containing pyrite and free gold. The Huronian wall rock also contains abundant disseminated sulphides and appears to have been otherwise affected by the vein solutions. Free gold seems to be associated with the sulphides, appearing most plentifully in rust-filled cavities formed by oxidation of pyrite.

The veins cut and are accordingly younger than the diabase. They are also confined to the immediate neighbourhood of this intrusive. The writer does not know of any other gold-bearing veins of the same age in this region except a silver-cobalt vein at the Mann mine in Gowganda district which also carries gold, a similar occurrence recorded from North Williams township, and certain auriferous quartz veins in quartz diabase near Lake Abitibi[1]. Only this one occurrence has been examined by the present writer, but from descriptions by Coleman and others[2] the gold-bearing veins found at other points near Wanapitei lake are similar in composition and geological relationships, and may, therefore, have had a common origin. What their source may have been remains unproven, but such evidence as is available suggests a connexion with the diabase.

IRON.

Banded iron formation occurs in seven distinct localities in Onaping map-area. None of these have any present economic value, but as two of them have already been exploited, mention may be made of their general character. A more extended account is given of Moose Mountain mine, situated just beyond the southern border of the map area, which is already an important producer of iron ore.

Burwash Lake.

'Keewatin' schists, the home of banded iron formation, are represented at Burwash lake only by highly metamorphosed remnants imprisoned in the intrusive granite-gneiss. These inclusions vary from a few inches up to some thousands of feet in length and consist either of a highly crystalline hornblende schist or of iron formation. Seemingly, iron formation resisted assimilation best of all the materials invaded by the granite magma, for it composes all the larger inclusions and is in much larger proportion to the other vestiges of the schist complex than is the case in schist areas that have not been invaded and assimilated by granite. About a dozen such patches of iron formation were found within an area of 10 square miles east and southeast of Burwash lake and probably others have been overlooked. The largest is a half mile long but not over 100 feet wide.

The iron formation consists of the usual alternating bands of silica and magnetite, but there is also present a considerable quantity of bright green hornblende, developed in all probability by the intense metamorphic action of the granite-gneiss. Grey is the prevalent colour. No indications were observed of ore concentration; the richest formation would probably contain less than 30 per cent of iron. A considerable amount of surface stripping and diamond drilling was done upon the larger bodies, in the interests of Mackenzie and Mann, Ltd., the results of which led to their abandonment.

Shiningtree Lake.

A description of the iron formation east of Shiningtree lake and the exploration work being done at the time by Mackenzie and Mann, Ltd., was published in the Summary Report for 1910. No important ore bodies were found and the property was abandoned in 1911.

[1]Report of Bureau of Mines, Ont., vol. XVIII, part 1, pp. 263–283.
[2]Report of Bureau of Mines, Ont., vol. V, p. 262; *ibid.*, vol. VII, p. 86.

Moose Mountain.

Moose Mountain iron range lies in Hutton township, 25 miles north of Sudbury. It is the only economically important part of a discontinuous belt of iron formation that extends from Wanapitei lake northwestward to Onaping lake. The first mining locations on this range were taken up in 1900 and in 1903 Moose Mountain Co., Ltd., was incorporated, with a capital of $2,000 000 to develop them. A mining equipment was installed in 1906 and a railway spur 4 miles long built from the mine and its dependent village of Sellwood to the Canadian Northern Ontario railway. Since then 157,400 tons of ore have been mined and shipped to Key Harbour on Georgian bay where ore docks have been built for transferring the ore to lake vessels. The rail haul from Sellwood to Key Harbour is 82 miles.

Brief geological descriptions of the range have been written by Coleman[1], Leith[2], and Miller[3]. Also during the field season of 1912, Mr. E. Lindeman, of the Mines Branch, Department of Mines, directed topographic, geologic, and magnetometric surveys of the range and its ore bodies, the results of which are now being prepared for publication. This will be by far the most complete report upon the range. The present short account, based on two days' examination of the property, is intended to deal only with recent changes in the treatment of the ore that may influence the iron mining industry of Ontario in the future, hence the succeeding geological description is limited to a few necessary statements concerning the ores and ore bodies.

The range consists of over a dozen more or less distinct, banded ore bodies elongated in a northeast-southwest direction along the strike of the highly folded Keewatin schists, which form the immediate country rock. Both schists and ore bodies are intruded by tongues from a neighbouring batholithic granite area. The dimensions of the ore bodies cannot be given accurately, but they are sufficient to indicate the existence of many million tons of ore. Much the greater part is a banded iron-formation of dull grey colour, consisting of alternating light bands of silica and black bands of magnetite. As shown by analysis No. III below, this material is too poor in iron to be ordinarily regarded as an ore. In ore body No. I, however, the lean formation grades sharply into a solid black ore in which the original banded structure is only faintly visible, the pale silica bands being replaced by magnetite or amphibole. The composition of this ore after magnetic cobbing is given in analysis No. II.

	I.	II.	III.
Fe	36·70	65·58	54·06
P	0·057	0·019	0·097
SiO_2	45·20	8·69	12·94
Mn	0·04	0·04	0·19
Al_2O_3	0·25	0·20	1·18
CaO	1·06	0·46	3·51
MgO	1·59	0·41	3·07
S	0·024	0·029	0·10
Ti	....	....	None.
H_2O	0·15	....	2·60

I. Average sample of lean banded ore from Deposit No. 2, Moose Mountain.
II. Ground and magnetically concentrated product of same.
III. Selected ore from deposit No. 1, Moose mountain.

[1] Coleman, A. P.—Hutton Township Iron Range: Report, Ont. Bur. Mines, vol. 13.
[2] Leith, C. K.—Moose Mountain Iron Range: *Ibid.*, vol. 12.
[3] Miller, W. G.—Iron Ores of Nipissing District: *Ibid.*, vol. 10.

Adverse circumstances have induced Moose Mountain Company to adopt magnetic separation methods in handling their ore and, from time to time, to modify and extend these methods. Although hand sorted, the first shipment of Moose Mountain ore, from No. 1 deposit, was refused by the purchaser; it contained only 53·80 per cent of iron and was not a good smelting ore. After this the ore was crushed finer and passed over a single drum magnetic cobber, but this product was dusty and still unfavourably regarded. However, improvements were made until the partly concentrated ore found a ready market. Then the plant was enlarged in 1910. Up to the present time mining has been confined to the rich ore in deposit No. 1. An open pit 300 feet long, 70 feet wide, and 40 feet deep has been mined out and underground work also carried to a depth of 130 feet. But the company now intends to develop the magnetic separation process still further and utilize the lean banded formation also. A new mill has been built and equipped at a cost of over $300,000 to crush, magnetically concentrate, and briquet this ore. Most of the machinery was installed when visited in October and is expected to be in regular operation in May, 1913.

The plant consists of a concentrating building in which the ore is pulverized, magnetically concentrated, and freed of all but enough water for briquetting purposes, and a briquetting building in which the moist concentrated ore is pressed into briquets and rendered coherent by sintering in a kiln. Producer gas for heating the kiln is generated in a third building. All the buildings are constructed of steel and concrete. The plant is driven and lighted by electricity purchased from the Wanapitei Power Co. and carried 35 miles over the Moose Mountain Company's own transmission line.

The ore from the mine is first reduced in a huge jaw crusher to lumps of about 6 inches diameter, dropped into skips and drawn up an inclined tramway to the top of the concentrating building, where it is stored in bins having a total capacity of 2,500 tons. From the bottom of these bins it is fed into crushers and reduced to powder. This crusher, which has been devised by the manager, Mr. F. A. Jordan, consists essentially of a heavily corrugated steel chamber within which a set of hinged hammers rotate at high speed. A lump of ore fed into the chamber is reduced to powder by alternate high velocity impacts with the rotating hammers and the corrugated roof. As the powder becomes fine enough to pass through a 100-mesh-to-the-inch screen it is carried out of the crusher by a suitably regulated air current. Four of these impact crushers, with tested capacities of 10 tons per hour, have been installed.

The pulverized ore from each crusher is mixed with water and flows to a battery of three Grondal magnetic separators, which removes the magnetite from its siliceous impurities. For finer grinding, if such is found necessary, there are four Hardinge conical 6 foot by 8 foot tube mills in which the concentrate may be further reduced and the resultant powder again concentrated in a second battery of Grondal separators.

The ore, as it finally comes from the separators, contains a large amount of water. This is reduced to 30 per cent by passing over Dorr classifiers. All but 15 per cent of the remainder, which is retained to render the moulded briquets coherent, is removed while the ore passes to the briquetting building, the wet ore being carried on an inclined belt which is agitated so as to remove all but the required amount of water.

A hydraulic press moulds the moist ore into briquets 2½ inches by 3½ inches by 6 inches, 225 at a time, and deposits them upon flat cars, which run into the sintering kiln. The tops of these cars are constructed of refractory material, fit tightly end to end, and make a free sand sealed contact with the edge of the kiln so that they form a continuous bottom for the kiln chamber and protect the running parts beneath. The kiln is 170 feet long and accommodates 29 cars, which enter at the

rate of one every fifteen minutes; in other words, the capacity of the plant is 400 tons per day. A temperature of 2,400 degrees Fahrenheit is found sufficient to slightly sinter the briquets and render them coherent enough for subsequent handling.

The briquetted ore is expected to possess a number of advantages in the iron-ore market which will tend to offset its cost of treatment. A 30-ton test sample of the lean ore represented by analysis No. 1, when ground and magnetically separated at Sheridan, Pa., yielded a product high in iron and low in phosphorus, as shown in analysis No. 2. In the briquetting process all water and sulphur are driven off and the magnetite altered to hematite, so that the final product will be an anhydrous bessemer ore exceptionally high in iron. Also the porosity and convenient size of the briquets should render it a good smelting ore.

Present conditions in the iron industry of Ontario invest these developments at Moose mountain with considerable general interest. The eight blast furnaces working in Ontario during 1911 smelted 822,174 tons of ore, 82 per cent of which was imported. This scarcity of Ontario ore is due not altogether to a lack of ore deposits but in considerable degree to the prevalent leanness of most of the known deposits. The Keewatin schists in the Pre-Cambrian region of Ontario include many ranges of banded iron formation carrying up to 35 per cent of metallic iron, but too lean in its natural condition to be merchantable. This iron is almost always in the form of magnetite, or mixtures of magnetite and hematite. Silica is the chief impurity. As a rule the phosphorus content is low and titanium frequently absent. Sulphur is sometimes abundant, but as this constituent is eliminated in the briquetting process its presence is not detrimental. In brief, much of the banded iron-formation in other parts of northern Ontario is similar in physical and mineralogical characters to the lean ore at Moose mountain, and, therefore, amenable to the same treatment. Some of these ranges are not easily accessible or would have a prohibitive rail haul, and many are too small or too low grade for present exploitation, but there are probably some to which the new process at Moose mountain, if it proves successful, may be applied in the future.

A GEOLOGICAL RECONNAISSANCE FROM LAKE KIPAWA VIA GRAND LAKE VICTORIA TO KANIKAWINIKA ISLAND, BELL RIVER, QUEBEC.

(*M. E. Wilson*)

Introduction.

With the construction of the National Transcontinental railway, transportation facilities were afforded to a vast extent of country in northern Quebec which hitherto had been almost inaccessible, and with regard to the natural resources of which but little detailed information was available. It has furthermore been proposed that a railway be constructed from the National Transcontinental to James bay by way of the Nottaway River basin, so that information with regard to the geological and other economic possibilities of this district was also demanded. For these reasons, the past field season was spent by the writer in making a geological reconnaissance throughout a belt of country, extending from Lake Kipawa to Grand Lake Victoria and thence via the Bell river northward to Kanikawinika island, a point about 80 miles north of the National Transcontinental railway.

Since a large part of the lakes and rivers of the region traversed had already been surveyed by the Provincial Department of Lands, Forests, and Mines with sufficient accuracy to be used in the publication of a reconnaissance map, no instrumental surveys were made, but the existing maps were supplemented by track sketches of such lakes and rivers as had not been previously mapped. By this method of work a much larger extent of country was examined than could have otherwise been attempted

I was assisted in the field by Messrs. L. E. Dagenais and C. H. B. Cooper, both of whom performed their work in a most satisfactory manner.

Location and Area.

The region traversed lies in northwestern Quebec and extends in a northeasterly-southwesterly direction through the central part of Pontiac county and the eastern part of Abitibi district. It has a length of approximately 200 miles and an approximate width of 35 miles, the total area examined being 5,000 square miles (See Index, Fig. 10).

Previous Work.

Geological work in this region up to the present has consisted entirely of reconnaissance surveys along some of the principal waterways.

In 1887, Dr. Robert Bell and his assistant, Mr. A. S. Cochrane, ascended from Lake Timiskaming to Grand Lake Victoria, by way of Lake Kipawa, Birch, Sasiginika, Wolf, Grassy, and Du Moine lakes. From Grand Lake Victoria, Dr. Bell continued his explorations to the head-waters of the Ottawa, thence down the Gatineau river, while Mr. Cochrane proceeded northward across the height of land and descended the Bell river to a point 10 miles north of Shabogama lake. He then retraced his course to Grand Lake Victoria and returned to Lake Timiskaming by the Ottawa river and Lac des Quinze. In 1895, Dr. Bell again returned

to Grand Lake Victoria and continued the exploration of the Bell river, begun by Mr. Cochrane in 1887, to its outlet into Lake Mattagami, and then proceeded down the Nottaway to James bay.

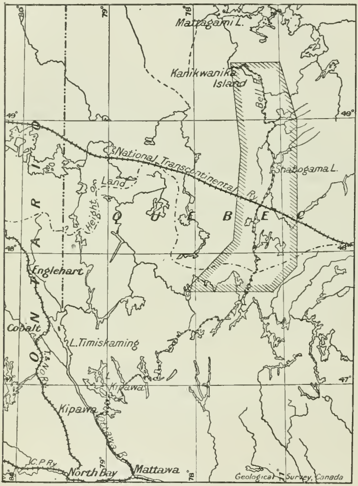

Fig. 10.—Index showing route traversed and country described.

In 1896, Dr. Bell, assisted by Mr. R. W. Brock, spent a portion of the field season of that year in making reconnaissance surveys of the Majiskan and other tributaries of the Bell river.

In 1907, Mr. W. J. Wilson explored some of the waterways and survey lines adjacent to the National Transcontinental railway to supplement the earlier work of Dr. Bell.

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General Character of the District.

TOPOGRAPHY

The whole of the region traversed lies within the great Laurentian plateau which occupies the larger part of northeastern Canada, but it exhibits two distinctly different phases of the plateau topography, the southern portion of the area constituting what may be described as the rocky hill country, while the northern portion belongs to what is generally called 'the clay belt'. The rocky hill country presents all those physiographic features which generally characterize a surface of low relief which has been subjected to continental glaciation, but in the clay belt, these have been largely buried beneath a mantle of stratified clay which has been built up to form local constructional or depositional plains.

The belt of territory examined extends for 200 miles through the central part of the Laurentian plateau and consequently possesses a relief approximately the same as the general relief of that physiographic province. The lowest point in the area has an elevation of about 850 feet above the sea, and the highest about 1,500 feet, the average for the whole district being approximately 1,100 feet. Throughout the rocky hill country the surface of the region, while possessing a low general relief, is minutely and exceedingly rough, for steep scarps, rocky hills, and abrupt depressions occur everywhere. Throughout the clay belt, on the other hand, these minor irregularities in the rocky surface have been filled by the deposition of the stratified clay, so that only the more prominent irregularities in the rocky floor protrude through the clay as hills.

The approximate elevation of some of the more prominent points along the route traversed are as follows:—

Lake Kipawa	873
Lake Ostoboning	928
Lake Ogascanan	1,040
Trout lake	1,150
Grand Lake Victoria	1,103
Height of land	1,148
Christopherson lake	1,099
Lake Obaska	1,033
Bell river at crossing of Transcontinental	994
Shabogama lake	994
Bell river at Kanikawinika island	852

The region is divided by the height of land into two drainage basins, the southern of which includes nearly the whole of the rocky hill country and belongs to the Ottawa River system, while the northern includes the clay belt portion of the region and drains into the Nottaway river. The drainage features of these two topographic phases of the Laurentian plateau are typically developed in this district. The rocky hill country is characterized by innumerable lakes, abundant waterfalls, rivers without valleys, and valleys without rivers—all features which

result where continental glaciation has imposed a youthful drainage system on a region of low relief. In the clay belt, the drainage is largely effected by rivers which possess wide and meandering channels throughout the greater part of their course, but here and there waterfalls occur at points where they have cut their way through the clay to the underlying bed-rock. In this way, a drainage system developed on the surface of the clay belt is being superimposed on the underlying solid rock, but dissection has not proceeded far enough as yet for the rivers to effect even the partial drainage of their basins, for large areas of almost treeless undrained muskeg occur in which no streams have been formed.

AGRICULTURE

In the southern part of the region traversed—the rocky hill country—there is very little land suitable for agriculture, but the clay belt of the north affords a very excellent soil for the growth of agricultural products. The thick growth of vegetation which everywhere covers the surface of the clay at present, keeps the soil at a lower temperature than would otherwise be the case, but excellent crops of potatoes are grown each year by the Indians of the district, and with the clearing of the land it is probable that all the common cereals and vegetables will grow in the region without injury from frost.

FLORA

The flora of this region lies on the border line between the Canadian and Hudsonian floral belts, or in the subarctic subdivision of Canadian flora, according to the classification of Professor Macoun of the Geological Survey, and includes all the species typical of this forest zone. Red and white pine occur in great abundance in the southern part of the district, but gradually diminish in size and number to the northward as far as the height of land. To the north of the height of land, only a few pine in scattered groves were seen. The various trees suitable for the manufacture of wood pulp, occur abundantly throughout the whole region and particularly in the clay belt where black spruce constitute the principal forest species present. Other trees common in the region but of less commercial value are banksian pine, white and yellow birch, poplar, balm of Gilead, white cedar, balsam, and tamarack.

SUMMARY AND CONCLUSIONS

The geological investigations carried on during the field season of 1912 consisted, for the most part, of an examination of the rocks of the basement complex occurring throughout a portion of the southern part of the Laurentian plateau. As a result of the investigation, it has been found that in this region the complex may be divided geographically into three divisions—a northern volcanic belt (Abitibi group), a southern limestone belt (Grenville series), and an intermediate belt of banded gneisses. It was also found that the banded gneisses of the central belt had the structures of folded sedimentary rocks, the folds having a northeasterly-southwesterly trend.

From the facts observed, it is inferred that the central belt of banded gneisses was originally a batholithic geanticline lying between a southern and northern geosyncline of sediments and volcanic flows. It is also inferred that the banded structure of the central gneissic complex originated (1) because the batholithic belt became heterogeneous in part by the stoping off and infolding of its roof rocks but chiefly by differentiation, and (2) because the mountain-building stresses which folded the overlying rocks continued during and after the consolidation

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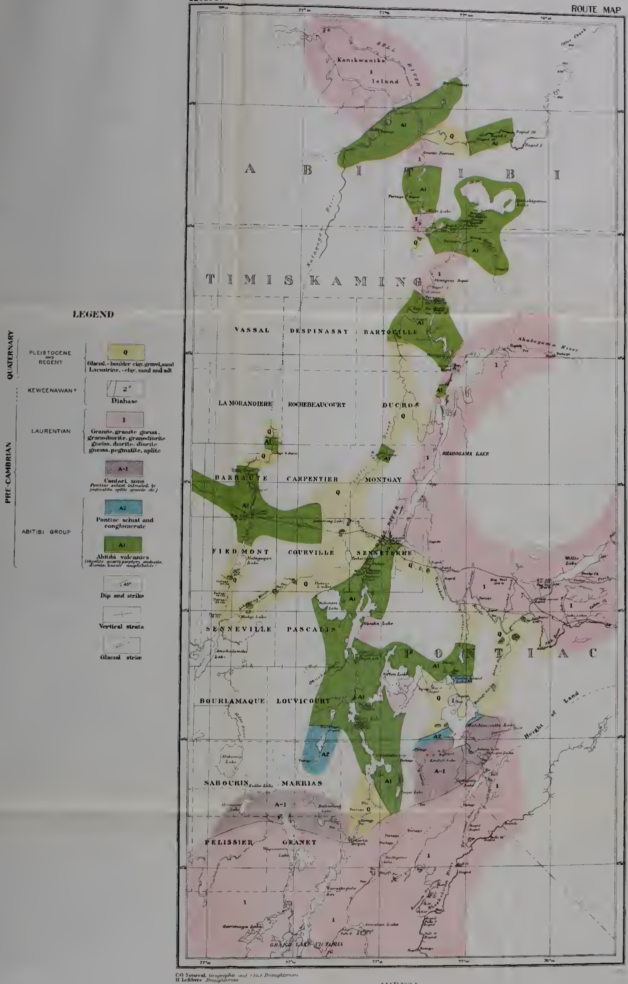
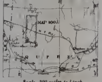
GEOLOGICAL SURVEY
R W Brock, Director

GEOLOGY

ROUTE MAP



C O Senécal, Geographer and Chief Draughtsman
H Lefebvre, Draughtsman



Scale 300 miles to 1 inch

MAP 100A
(Issued 1913)

BELL RIVER

QUEBEC

Scale, 1/506,880

Miles

Kilometres

8 MILES TO 1 INCH

GEOLOGY		
W J WILSON	1906-1907	
M E WILSON	1912	
GEOGRAPHY		
DEPARTMENT OF LANDS AND FORESTS QUEBEC	1906-1912	
W J WILSON	1906-1907	
M E WILSON	1912	
NATIONAL TRANSCONTINENTAL RAILWAY	1904-1912	

To accompany Summary Report by M E Wilson 1912

of the batholithic magma so that the variations in the batholithic belt were squeezed out into thin lenses and folded in the manner observed.

No mineral deposits of commercial value, under present conditions of operation, were seen, but the region possesses other natural resources in its timber, fish, fur-bearing animals and waterpowers, while the clay belt affords an excellent soil for the growth of all the hardier varieties of agricultural products.

General Geology.

GENERAL STATEMENT

From an examination of a general geological map of eastern Canada it may be seen that a great belt of gneissic rocks (Laurentian) extends continuously from Georgian bay to the gulf of St. Lawrence. On the southern border of this belt, the gneisses intrude and include bands and masses of crystalline limestone and other sediments which are generally known as the Grenville series. If a geological section be made proceeding northward from the region where the rocks of the Grenville series are abundant, towards the gneissic belt, it is found that the masses and bands of included Grenville sediments gradually diminish in size and number, and are finally replaced entirely by the banded gneisses. To the north of the gneissic belt, in the vicinity of Lake Timiskaming and extending westward, to the north shore of Lake Huron and eastward, to Lake Mistassini, surface rocks—volcanic flows, conglomerate, greywackes, arkose, and slate—occur infolded and intruded by granites and gneisses and gradually disappear when traced (southward) in the direction of the central belt of the gneisses. Throughout western Quebec and northeastern Ontario, therefore, there is everywhere a basal complex which consists, in part, of surface rocks—that is rocks formed at, or near, the earth's surface—and, in part, of plutonic granites and gneisses, the latter having their greatest development in a northeasterly-southwesterly trending axial belt which divides the surface rocks into two lithologically different areas. In the southern of these areas, limestone is the dominant surface rock, whereas in the north, volcanic types are most abundant.

In the region north and west of Lake Timiskaming a group of approximately flat-lying clastic sediments known as the Cobalt series, rests on the truncated and base-levelled surface of the older complex, described in the previous paragraph. Also, in the vicinity of Lake Mistassini[1], in the Sudbury district[2], and on the north shore of Lake Huron[3], sedimentary rocks lie unconformably on the surface of the older complex, those occurring on the north shore of Lake Huron constituting the original Huronian rocks of Sir William Logan. The relationship of the sediments occurring in these various localities to one another has not been ascertained, but they are alike in that they are all separated from the underlying complex by a most profound erosional and structural unconformity.

Throughout northwestern Quebec and northeastern Ontario both the older complex and the overlying sedimentary series are cut by intrusions of diabase and related rocks which took the form of dykes in the older complex but spread out as sills in the overlying sediments. Since these rocks are lithologically similar to the igneous members of the Keweenawan series of the Lake Superior region and were intruded at about the same time (late Pre-Cambrian or early Palæozoic), and occur throughout the whole region from western Quebec to Lake Superior,

[1] Geology and Mineral Resources of the Chibougamau Region: Dept. of Col., Mines, and Fisheries, Quebec, pp. 134–138.

[2] Report of the Ont. Bureau of Mines, vol. XIV, part 3, p. 9, 1905.

[3] Geology of Canada, p. 52, 1863.

they were probably derived from the same magma as the Keweenawan igneous rocks and are approximately of Keweenawan age.

With the exception of a few outliers of Palæozoic sediments, the Keweenawan(?) intrusives are the youngest of the solid rocks occurring throughout the whole region from western Quebec to Lake Superior, but the surface of these ancient rocks is everywhere to a large extent hidden from view by a mantle of unconsolidated Pleistocene and Recent deposits. These consist chiefly of glacial drift although, in part of the region, the latter is overlain by stratified clay and sand, material laid down from a huge post-Glacial lake which covered a considerable area within the Laurentian plateau following the retreat of the last continental ice sheet.

The regional geological succession outlined above is in general the same as that of the district traversed during the past summer, except that no Huronian rocks were seen in place, although a large boulder of conglomerate similar to that of the Cobalt series was observed on the shore of Lake Matchimanitou. It is possible, therefore, that an outlier of the Cobalt series is present somewhere in the district.

Table of Formations.

In the following table the geological formations are arranged as nearly as possible in descending order with respect to age.

Quaternary	Post-Glacial	Stratified lacustrine clay and sand.
	Glacial	Gravel, sand, boulders, boulder clay.
	Unconformity.	
Pre-Cambrian (?)	Keweenawan ?	Nipissing diabase.
	Igneous contact.	
Pre-Cambrian	Cobalt series	(Not seen in place).
	Unconformity.	
	Laurentian	Granite, granite-gneiss, syenite, syenite-gneiss, granodiorite, granodiorite-gneiss. Diorite, diorite-gneiss, amphibolite, amphibolite-gneiss. Pyroxenite. Garnetiferous mica schist, aplite, pegmatite.
	Igneous contact.	
	Abitibi group[1]	Pontiac schist, etc., mica schist, staurolite schist, iron formation, conglomerate. Abitibi volcanics—andesite, basalt, etc.
	Grenville series[1]	Limestone.

GRENVILLE SERIES.

Distribution.

Lake Kipawa, the point from which the reconnaissance of the past field season was begun, lies within the central belt of the Laurentian banded gneisses and hence beyond the last known outcrop of rocks belonging to the Grenville series which, as has already been explained, have their greatest development in a belt extending along the southern border of the Laurentian highlands. On the north shore of Brennan or Sairs lake, one of a succession of lakes which together constitute the upper Kipawa river, two small irregular lenticular masses of crystalline limestone included in the banded gneisses were observed. This occurrence of the Grenville series lies to the southeast of Lake Kipawa and at the extreme southern end of the belt of country examined. From this point northward, no outcrops of limestone were observed, and it is probable that the Brennan Lake limestone marks the extreme northern limit of the Grenville series in this region.

[1] Age relationship of the Abitibi group and the Grenville series unknown.

Lithological Character.

The Grenville limestone occurring on the shore of Brennan lake is a coarse white variety consisting of calcium carbonate traversed by numerous seams or zones of tremolite. Along the contact of the limestone and the surrounding gneiss, lime silicates have developed which, when examined under the microscope, were found to consist of tremolite and diopside.

Structural Relations.

The Brennan Lake limestone occurs in two lenticular masses about 10 feet long and from 2 to 3 feet in thickness. These have almost a horizontal attitude and thus conform to the foliation of the enclosing gneiss which, at this point, lies almost flat. From the contorted and lenticular form of the limestone masses and the conformity of the lenses to the foliation of the gneiss, it is evident that the limestone has been subjected to intense deformation, while from the occurrence of lime silicates on their margin it is also evident that considerable contact action between the gneiss and the limestone has taken place.

The relationship of the rocks of the Grenville series to older formations has nowhere been observed. It is presumed that the Grenville limestone was originally a sediment deposited in a manner somewhat similar to the limestones of more recent formations, but, in this particular locality at least, the floor upon which it was laid down was long ago destroyed by batholithic invasions of granitic magma.

Age and Correlation.

The Grenville series as has already been stated, is the name applied to limestone and other sediments which occur along the southern border of the Laurentian highlands as masses and bands infolded within the Laurentian granite and gneiss. These rocks are lithologically similar wherever they occur, and as far as known, are in conformable succession and hence are believed to constitute a single series. The occurrence of limestone on Brennan lake has been correlated with the Grenville series because, (1) it is lithologically similar to the dominant member of the series, (2) it is located in the same region, and (3) like the rocks of the Grenville series, it is infolded in the Laurentian banded gneisses.

ABITIBI GROUP.

Introductory Statement.

It has been previously explained that, to the north of the central belt of Laurentian banded gneisses, there is a region extending from Lake Mistassini to Lake Huron, throughout which volcanic flows and sedimentary rocks occur abundantly in the older complex. These rocks, like the Grenville series, are highly folded, more or less metamorphosed, and, so far as has been observed, are always intruded by the Laurentian granite and gneisses. The relationship of the various rocks belonging to this ancient geological province are, as yet, imperfectly understood, but they are alike in that they all belong to the basement complex which lies beneath the pre-Huronian erosion surface.

For many years the unconformity existing between these rocks and the overlying slightly disturbed, sedimentary series was not recognized and they were called Huronian. But with the progress of detailed investigation the existence of a striking erosional and structural unconformity became evident, and the vol-

canics and other rocks of the complex were then designated Keewatin on the assumption that they were the equivalent of similar rocks occurring in the Lake of the Woods region, 500 miles to the westward. In this way, it became customary to divide the older complex of the region into two divisions—the Keewatin, which included the surface rocks composed largely of volcanics, and the Laurentian, which consisted largely of plutonic granite and gneiss.

In recent years, it has been found, however, that the older complex included a much larger proportion of sedimentary rocks—conglomerate, slate, greywacke, arkose, etc.—than was formerly supposed, and to these, various local names —Pontiac schist, Fabre series, Timiskaming series, etc.—have been given. There is evidence in some localities that these sediments and the volcanics are interbedded and in most localities throughout this northern province, either because of the highly-deformed condition of the rock, or because of the paucity of exposures, or because of the lithological uniformity of the volcanic flows, it is not possible to separate these various rocks into stratigraphical divisions. For these reasons, it seems necessary to class all the surface rocks together into one group regardless of possible differences in age, making merely such divisions as are convenient for the purpose of lithological description.

In accordance with the foregoing conclusion, the writer has adopted the term Abitibi group to include all the surface rocks of the older complex occurring in the northern geological province—that is occurring throughout the Lake Huron-Lake Timiskaming-Lake Mistassini region. In the particular district to which this report refers, the Abitibi group can be conveniently classified for the purpose of description into two subdivisions, these being the Pontiac schist and conglomerate and the Abitibi volcanics.

Pontiac Schist and Conglomerate.

Distribution.—In previous reports on districts in northwestern Quebec[1] it has been pointed out that along the northern margin of the central belt of gneisses, a band of mica schist occurs which, to the northward, passes gradationally into arkose, greywacke, and conglomerate, the mica schist having apparently been formed by the contact action of the granite and gneiss on these sediments. It is now known that this band of mica schist and other rocks extends almost continuously from the interprovincial boundary to Lake Matchimanitou, a distance of approximately 110 miles, and throughout this interval has an approximate average width of over 10 miles. These rocks, therefore, occupy an area of at least 1100 square miles and constitute the largest continuous belt of sediments in the older complex throughout the whole of the Lake Timiskaming region.

In the district to which this report refers, mica schist similar to that occurring farther to the westward was observed at the north end of Grand Lake Victoria, to the north of Wapusanan lake, on the Sleepy river, and on Matchimanitou lake. Two small outcrops of squeezed conglomerate, the matrix of which has been converted into mica schist, were also seen on the east shore of Garden Island lake. The belt of mica schist is not continuous, however, for in the vicinity of Christopherson and Simon lake, the volcanics of the Abitibi group occur. This interruption is probably related in some way to the structure of the rocks for the foliation in the volcanics changes abruptly from the general east-west direction to a few degrees west of north.

[1] Summary Report, Geol. Surv., Can., p. 122, 1908.
Summary Report, Geol. Surv., Can., p. 175, 1909.
Summary Report, Geol. Surv., Can., pp. 275–276, 1911.
'The Larder Lake District, Ont., and Adjacent Portion of Pontiac County, Que.': Memoir No. 17, Geol. Surv., Dept. of Mines,
'The Kewagama Lake Map Area': Memoir No. 39, Geol. Surv., Dept. of Mines.

Lithological Character.—The predominating rock of the Pontiac division of the Abitibi group is a fine-grained, rusty biotite schist, but, locally, there is associated with this rock, some staurolitic biotite schist, iron formation, and conglomerate. The staurolitic mica schist occurs in a belt several hundred feet in width outcropping on both the east and west shores of Lake Matchimanitou. It resembles the typical mica schist in appearance, but contains numerous crystals of staurolite which are commonly an inch or more in length. Dark red garnet also occurs abundantly in the staurolite zone and at one point on the east shore of the lake, bands of magnetite from one-fourth inch to 2 inches in width, occur interlaminated with the schist, thus transforming the rock into an iron formation. The conglomerate associated with the mica schist was observed in two small exposures occurring on the east shore of Garden Island lake. The rock at these points resembles the typical mica schist found elsewhere, but contains pebbles of quartz, biotite granite, and other rocks. The pebbles have all been greatly deformed, the more resistant being slightly flattened and the less resistant squeezed out into thin lenses.

Examined microscopically, the mica schist can be seen to consist essentially of biotite and quartz with usually some feldspar—chiefly orthoclase. The biotite, in some thin sections examined, was largely altered to chlorite and the orthoclase sericitized. The accessory minerals observed were garnet, apatite, magnetite, and hornblende. The texture of the mica schist is uniformly fine grained, the mineral having the mosaic-like (crystalloblastic) arrangement so characteristic of the paraschists and gneisses. The feldspar and quartz grains as well as the biotite are generally flattened parallel to the plane of foliation.

The staurolitic mica schist and iron formation when examined under the microscope, can be seen to differ from the ordinary variety in that they contain no feldspar. The staurolite crystals are also seen to be discontinuous, forming merely a network around grains of quartz. The biotite commonly terminates abruptly at the margin of the crystals of staurolite and garnet, but in some sections it bends around these minerals giving them an augen-like appearance. The magnetite bands which occur in the schist when examined under the microscope, are found to consist essentially of magnetite, quartz, and biotite. They pass into the mica schist transitionally by a gradual increase in the biotite and quartz content, and a corresponding decrease in the proportion of magnetite. As in the case of the ordinary mica schist, the biotite in the staurolitic band is generally more or less chloritized. The accessory minerals observed include sillimanite, epidote, hornblende, and apatite.

Structural Relations.—The internal structural relations of the Pontiac schist and conglomerate are so complex that little detailed information has been obtained with regard to these features, beyond the fact that the deformation to which the schist and conglomerate has been subjected has been most intense. They are everywhere highly foliated, the foliation having generally a vertical or nearly vertical attitude, but the extreme intensity of the deformation is most apparent where variations from the general uniformity of the mica schist occurs. Thus the iron formation and the dykes of pegmatite and aplite have been crumpled and broken in an almost incredible manner. Many of the pegmatite dykes have been completely disrupted into fragments ranging from an inch or less in diameter to huge masses. The larger part of the disrupted material has been squeezed subsequent to disruption so that the fragments occur in augen-like forms strung out parallel to the strike of the schist.

The Pontiac schist and conglomerate were not seen in contact with the original surface upon which they were deposited, but from the character of the fragmental material they contain, some inference may be drawn as to the composition of the rocks from which they were derived. Their relationship to the Abitibi volcanics—the remaining portion of the Abitibi Group—is unknown. The fact that the con-

glomerate contains pebbles of greenstones indicates that there were volcanic rocks present in the region at the time the conglomerate was being laid down, but, on the other hand, the occurrence of the schist, conglomerate, etc., in a narrow band extending for 100 miles along the northern margin of a great granitic axial belt, suggests that they have been folded up into their present attitude in company with the intrusion of the granite and gneiss, and, just as in the vicinity of laccolithic intrusions the older strata occur adjacent to the laccolith, so the schist, conglomerate, etc., which occur adjacent to the intrusive, should underlie the volcanics which occur farther to the northward. The rocks of this northern province, however, have suffered so many vicissitudes, and are so exceedingly complex, that it is not possible to draw any positive conclusions as to their structural relationships.

The relationship of the Laurentian rocks to the Pontiac schist and conglomerate is discussed in a later section of the report, here it is only necessary to state that wherever their contact was observed the latter were always intruded by the former.

Origin.—The Pontiac schist and conglomerate were originally, no doubt, water-lain sediments, but the precise character of the body of water from which they were deposited is not apparent. Their general clastic character and the heterogeneity of the fragments contained in the conglomerate, indicates that they were deposited in shallow water and not far distant from their source of supply. But the occurrence of a band of staurolitic schist and iron formation in the mica schist is a somewhat unusual association, for the mineralogical composition of the staurolitic schist and iron formation indicates that they consist largely of alumina, iron oxide, and silica, these elements being those which commonly result as end products in mature weathering, whereas the characteristics of the sediments elsewhere indicate imperfect decomposition and lack of sorting.

Abitibi Volcanics.

Distribution.—It has already been stated that the Abitibi volcanics are limited in western Quebec to a northern geological province which extends from near Lake Mistassini to Lake Timiskaming. The volcanics are not continuous throughout this belt, however, for they are intruded here and there by batholithic masses of granite, granodiorite, and related rocks, similar in composition to the great gneissic complex which occurs so extensively farther to the south. In the region traversed during the past field season, the Abitibi volcanics occur interruptedly throughout the whole of the territory adjacent to the Bell river from Christopherson lake northward, and are much more extensive than is indicated on the existing maps, because, on these, many disconnected small batholiths of granite which are separated by the volcanics have been joined together as if in continuous areas.

Lithological Character.—The Abitibi volcanics, as their name implies, are largely composed of lava flows, but they also include some dyke rocks similar in mineralogical composition and texture to the lavas. Where the volcanics have undergone the least alteration they are seen to consist of rhyolites, rhyolite porphyries, dacites, andesites, and basalts. These have all suffered more or less metasomatic alteration and in places have also been converted into schists, the acid types passing into sericite schist and the basic into chlorite schist. Near the contact of the granite batholiths and the volcanics amphibolites are commonly developed.

When examined in thin section under the microscope, all of the volcanics are seen to have been largely replaced by secondary minerals. The rhyolites and dacites consisted originally of fine-grained quartz and alkalic feldspar, but, in most places the feldspar have been largely replaced by sericite, zoisite, and epidote. Other minerals commonly present are hornblende, biotite, chlorite, and magnetite. The andesites are holocrystalline rocks largely composed of minute lath-like crystals of plagio-

clase. Like the rhyolites and dacites they have been metasomatically altered, the alteration products being zoisite, epidote carbonate, and chlorite. The thin sections of basalt examined were so completely altered as to retain little of their original composition. They consisted almost entirely of chlorite, epidote, zoisite, and carbonate. The schistose rocks derived from the volcanics do not differ greatly from the original rocks except that they are foliated and contain a greater abundance of sericite and chlorite; the sericite predominating in the acid types and the chlorite in the basic. The amphibolites are rocks of variable composition, the commonest minerals present being quartz, blue green hornblende, epidotized feldspar and magnetite.

Structural Relations.—It was not possible to work out the detailed structure of the Abitibi volcanics, partly because they are generally poorly exposed, partly because their structure is exceedingly complex, and partly because volcanic lavas are too uniform to afford definite horizons of reference such as commonly occur in bedded sedimentary rocks. It is apparent, however, from their foliated and brecciated character, in places, that they have suffered intense deformation. It is also apparent from the alternation of rhyolite, andesite, and basalt—portions of different lava flows—in adjacent outcrops that the flows are truncated at the surface and have been folded into a vertical or nearly vertical attitude.

The relationships of the Abitibi volcanics to other formations are discussed in other sections of the report, here it may be stated that their relationship to the Pontiac schist and conglomerate is unknown and that wherever they have been seen in contact with the Laurentian batholithic masses they were always intruded by the latter.

LAURENTIAN.

Definition of Laurentian.

The name Laurentian was first used by Sir William Logan to designate the great complex of gneisses and associated rocks which occur so extensively throughout the northern part of the St. Lawrence basin. As a result of the investigations carried on by Logan and his associates during the early years of the Canadian Geological Survey, it was shown that the Pre-Cambrian rocks of eastern Canada fell naturally into two main stratigraphical divisions—an older complex, the Laurentian, and a younger, much less disturbed and metamorphosed series, the Huronian. Logan further attempted to subdivide the basement complex into an upper Laurentian, consisting of anorthosite and anorthosite gneiss, and a lower Laurentian composed of two groups, the younger of which consisted largely of limestone and the older of gneiss.

Although Logan was mistaken in assuming that all the banded rocks of the older complex were originally sediments to which stratigraphic methods could be applied, yet it is evident from the above classification that he recognized the existence of the stratigraphic break which separated the Huronian from the older complex. Unfortunately, the significance of this most important fact in the stratigraphy of the Pre-Cambrian rocks of eastern Canada and the consequent necessity for a group name to include all the rocks of the older complex, was not generally recognized and in subsequent years it became customary to limit the term Laurentian to the granite and gneiss of the older complex[1]. It is with approximately the latter significance that the name is here used to include all the plutonic rocks of the basement complex regardless of possible difference in age. Defined in terms

[1] Report of the Special International Committee on the Correlation of the Pre-Cambrian rocks of the Adirondack mountains and the 'Original Laurentian Area' of Eastern Ontario. Jour. of Geology, vol. xv, pp. 191-217, 1907.

of geological relationships, the Laurentian includes the granites and gneiss which intrude the Grenville series and the volcanic complex (Abitibi group) of the Lake Mistassini-Lake Timiskaming-Lake Huron region. It would also include any plutonic rocks which might lie unconformably beneath either the Grenville series or the Abitibi group. The upper limits of the Laurentian are defined by the erosion surface that separates the basement complex from the Huronian, or defined more locally, the plane which separates the Cobalt series from the older complex in the Timiskaming region and the original Huronian rocks from the basement complex, on the north shore of Lake Huron. It is probable, according to this definition, that the anorthosites (Logan's Upper Laurentian) should be classed as Laurentian for these rocks are in part transformed into gneiss and belong essentially to the basement complex[1].

Lithological Character.

The rocks of the Laurentian complex may be classified (1) according as to whether they are massive or foliated, and (2) according to their mineralogical composition. To the massive rock types belong nearly all of the small batholithic masses which intrude the northern volcanic complex (Abitibi group) and to a much more limited extent some of the batholiths which intrude the southern limestone[1] complex (Grenville series). The foliated rocks on the other hand include nearly the whole of the central gneissic belt which separates the Abitibi group from the Grenville series. Classified according to mineralogical composition, the rocks of the Laurentian complex include the following types: granite, syenite, granodiorite, diorite, amphibolite, pegmatite, aplite, pyroxenite, and garnetiferous mica schist.

Granite and Granite-gneiss.—The granite and granite-gneiss of the Laurentian complex are granular, fine to coarse-grained rocks consisting essentially of quartz and alkalic feldspar—orthoclase, microcline, albite, and oligoclase—with biotite or hornblende or biotite and hornblende together, as ferromagnesian constituents. The biotite granite and granite gneiss is, however, much more common than the hornblendic variety. The common accessory minerals present are titanite, epidote, muscovite, garnet, apatite, zircon, and magnetite. The minerals cyanite, arfvedsonite, and aegerine were also found in some thin sections of granite gneiss occurring in the district to the north of the upper Kipawa river.

From the microscopic examination of thin sections of the granite and granite-gneiss it is seen that, in some places, the constituent minerals are remarkably fresh, while, in others, the feldspars are largely replaced by sericite and the hornblende and biotite by chlorite. Between these two extremes an intermediate rock type is also common in which sericitized feldspar occurs enclosed in a matrix of fresh, granular, quartz and microcline. In some sections, too, the minerals show by their undulatory extinction and granulated character that they have been subjected to intense mechanical deformation. In others, however, all these evidences of deformation are entirely wanting.

Syenite and Syenite-gneiss.—The syenite and syenite-gneiss is commonly a grey to rusty red rock which in most localities shows a remarkable tendency to disaggregate into its constituent mineral grains on the weathered surface. Examined under the microscope, the syenites and syenite-gneiss are seen to consist essentially of orthoclase, albite, microperthite, aegerine, and dark brown biotite. The accessory constituents observed are titanite, apatite, zircon, epidote, and magnetite. Under the microscope, it can also be seen that the disaggregation on the weathered

[1] Adams, F. D.—'Uber das Norian Oder Ober-Laurentian von Canada': Neues Jahrbuch fur Mineralogie, etc., vol. 8, 1893.

[2] According to Adams and Barlow, Memoir No. 6, Geol. Surv. Branch, Dept. of Mines, Can., 1910.

surface arises from irregular fractures which traverse the rock along the contacts of the mineral grains. The cause of the fractures is not apparent, but they are most probably related in their origin to the expansive pressure which no doubt accompanied the slight decomposition which has occurred in the aegerine. The syenite and syenite-gneiss are largely limited in their occurrence to the region adjacent to the upper Kipawa river, a few miles east of Lake Kipawa.

Granodiorite and Granodiorite-gneiss.—The granodiorite and granodiorite-gneiss are rocks of similar appearance to the granite and granite-gneiss, but their mineralogical composition shows them to occupy an intermediate position between diorite and granite. They contain much less quartz and orthoclase than the granite and correspondingly more plagioclase, and biotite is replaced by hornblende as the dominant ferromagnesian constituent. The accessory mineral constituents, mineral alterations, and evidences of mineral deformation are the same in the granodiorite as in the granite and granite-gneiss.

Diorite and Diorite-gneiss.—The diorite and diorite-gneiss are dark rocks containing an abundance of glistening crystals of hornblende. Examination under the microscope shows most of the rocks of this class to consist essentially of blue green hornblende and plagioclase, either albite, oligoclase, or andesine, but in some thin sections the proportion of plagioclase becomes so small that the rock might be more appropriately called a hornblendite. The common accessory minerals observed are garnet, magnetite, biotite, titanite, epidote, and zircon. The hornblende and biotite are commonly more or less altered to chlorite and the plagioclase in some sections is entirely replaced by sericite and epidote.

Mica Schist.—Within the central belt of banded gneisses there are several occurrences of mica schists which are possibly, in some cases at least, altered sediments, but because their mode of origin is in doubt and because they are closely associated with the gneisses they have been included in the Laurentian. One common type of mica schists occurring in the gneiss is a fine grained aphanitic rock containing broken and rounded fragments of feldspar, which give the rock a porphyritic appearance. This was observed in four widely separated localities on the south shore of Hunters lake, on Lake Ostoboning, at the north end of Trout lake, and near the Mink narrows on Twentyonemile bay, Grand Lake Victoria. Under the microscope, this schist is seen to consist of fragments of biotite, quartz, and feldspar enclosed in a fine-grained matrix of the same minerals. In some of the thin sections examined, the rock has an appearance closely resembling that of an arkose, but the abundant evidence of fragmentation in other sections suggests that it is in reality of igneous origin, and has assumed this clastic appearance as a result of deformation.

Mica schists resembling the Pontiac schist were also observed in several localities within the central belt of gneisses. These are fine-grained rocks consisting of biotite, quartz, orthoclase, and albite, and possess the mosaic-like, crystalloblastic texture so characteristic of the paragneisses. On Grand Lake Victoria, there is an area of these rocks several square miles in extent which contains a very large proportion of pink garnet. The presence of such a large proportion of this highly aluminous mineral indicates that the schist has the chemical composition of a sedimentary rather than an igneous rock and is probably a paragneiss.

Pyroxenite, Amphibolite, and Amphibolite-gneiss.—The rocks in this subdivision of the Laurentian have been grouped together because they are all largely composed of lime silicates, and hence are similar in chemical composition although, mineralogically, somewhat different. They occur chiefly as small lenticular masses in the banded gneiss, and are largely limited to a few localities near the south side of the central belt of gneisses. The pyroxenite consists chiefly of diopside, while the amphibolite is largely composed of tremolite, but both minerals are generally present in the former. Other minerals observed in these rocks were biotite,

scapolite, garnet, a carbonate and serpentine, the latter occurring as an alteration product from the diopside. At the east end of Birch lake, a small reef of a fibrous-looking rock occurs which resembles the pyroxenite and amphibolite in its mode of occurrence, but differs somewhat in composition. When examined microscopically, it was found to consist of anthophyllite, a carbonate, and a green mica.

Pegmatite and Aplite.—These rocks are among the most common in the Laurentian gneissic complex, occurring, in part, as thin lenses in the banded gneisses and, in part, as dykes transverse to the foliation and banding. They consist largely of quartz and alkalic feldspar (orthoclase microcline and albite), the names pegmatite or aplite being used according as the rock is coarse or fine grained. The less abundant minerals contained in these rocks are muscovite, biotite, apatite, garnet, allanite, graphite, molybdenite, epidote, titanite, and syenite. All the various phases in chemical and mechanical mineral alteration observed in the granite and granite gneiss are also present in the pegmatite and aplite, evidences of mechanical deformation being particularly apparent.

Structural Relations.

Foliation.—By far the larger part of the rocks comprising the Laurentian complex are foliated and for this reason are classed as gneisses. This foliation has been brought about, for the most part, by the parallel orientation of biotite plates and hornblende prisms, but also, in some cases, to a slight degree by the flattening of the feldspar and quartz in the same plane. Very commonly the biotite of the biotite gneiss is seen to 'eye' around small lense-shaped fragments of feldspar giving rise to the characteristic augen structure, which results from deformation. The trend of the foliation like that of the banding, indicates that it has the form of anticlines and synclines simulating the structure of folded sedimentary rocks in every respect.

Banding.—The most striking and the most characteristic structural feature of the central belt of Laurentian gneisses is the banding which is everywhere developed. The extreme complexity of the structures and the heterogeneity of the rocks contained in these banded gneisses, even in a single rock outcrop, are scarcely capable of description, yet, when examined over broad areas, this complexity and heterogeneity is so uniform that it becomes monotonous. The banding of the gneisses may arise either from (1) a variation in the proportion of minerals present in the same rock, or (2) by the alternation of bands of different rocks. Thus one of the most common types of banding is brought about by the alternation of bands of biotite gneiss containing varying proportions of biotite, so that a light band in which little biotite is present, alternates with a dark band containing a large proportion of biotite. In a similar manner, variations in theproportion of hornblende in the hornblende granite gneiss, the granodiorite-gneiss or the diorite-gneiss, result in a banded structure. The second type of banded structure in which the alternate bands are composed of different rocks may also be combined with bands of the first types and in this way an almost infinite variation in the composition of the bands may occur. The commonest rock of the banded gneiss is the biotite, or biotite-hornblende granite gneiss. Pegmatite, aplite, and quartz are also important, composing not less than 15 per cent of the whole. The proportion of other rocks is small, so that the central belt of Laurentian gneisses, considered as a whole, is granitic rather than dioritic in composition. The widths of the bands may vary from a fraction of an inch to hundreds of feet. When followed along the strike they are found to pinch out as though they were in reality thin lenses. This lenticular character is particularly evident in the case of the pegmatite, which commonly occurs in a succession of lenses around which the foliation in the surrounding gneiss bends in a manner very similar to that which occurs on a small scale around the augen of feldspar in the augen gneiss.

Granulation.—That granulation has occurred to a large extent in the banded gneisses is apparent from the abundance of augen gneisses and from the evidences of strain and fragmentation seen in some thin sections of the rocks. Recrystallization has accompanied granulation in many cases, however, for in many thin sections of rocks which had very evidently suffered granulation, the granular quartz and feldspar which surrounded the lense of the augen contained a large proportion of microcline and was much fresher in appearance than the central core.

Folding and Faulting.—The study of the structure of the banded gneisses indicates that they have been folded in a manner very similar to that exhibited by deformed sedimentary rocks. While the bands are not continuous over wide areas like sedimentary beds, yet, all the various types of folds are present on a small scale and, in places, anticlines and synclines nearly a half mile in cross section, can be recognized. These folds are generally pitching and since the strike of the bands is dominantly in a northeasterly-southwesterly direction, it is inferred that the banded gneiss has been folded into pitching anticlines and synclines trending, for the most part, in a northeasterly-southwesterly direction. In some places the biotite has been smeared out along the contacts of the bands, giving a slickensided appearance which has evidently resulted from differential movements accompanying the folding.

In describing the structure of the Laurentian gneisses[1] occurring in eastern Ontario, Adams and Barlow note that the foliation of the gneiss near the border of the batholith corresponds to the strike of the surrounding sedimentary rocks and conclude that the batholiths are anticlinal in their relationship to the Grenville series, the anticlinal axes trending N. 30° E. They also indicate the trendof the foliation and banding in the batholiths as commonly oval or elliptical in form, and while no statement is made by the authors as to structure of the gneiss it seems apparent from the trend of the foliation indicated, that the gneiss in that locality also has a folded structure similar to that of the central belt of gneisses of the Laurentian complex.

On the whole, faulting has been subordinate to folding in the Laurentian banded gneisses. Such faults as were observed can be classified into two types, the first of which are related to the folding occurring where overthrust folds have fractured. The second type of faults are fractures along which the bands of gneiss have been displaced and have no relationship to the folds. In some places, pegmatite dykes have formed in fractures of the second type.

External Relations.—The relations of the Laurentian complex to the rocks composing the Abitibi group and the Grenville series have already been indicated in the previous sections of the report. Wherever they have been seen in contact, the Laurentian is always intrusive into the latter, although the presence of pebbles of granite in the conglomerates of the Abitibi group, indicates that an older granite occurred, at one time if not at present, in the region.

Origin.

A discussion of the possible modes of origin of the Laurentian gneissic complex resolves itself into two problems: (1) are the banded gneisses of sedimentary or igneous origin? and (2) in what manner did the rocks become banded, folded, and foliated into their present condition?

Sedimentary or Igneous Origin.—The early Canadian geologists in common with geologists working in other parts of the world generally, assumed that banded gneisses owed their bedded-like structure to subaqueous deposition[2]. In the case

[1] Memoir No. 6, Geol. Surv., Dept. of Mines, Can., 1910.
[2] Geology of Canada, p. 29, 1863.
Sterry Hunt, Royal Society of Canada, vol. II, 1884.

of the Laurentian banded gneisses, this seemed particularly obvious, for they were bedded and folded like stratified sediments, and were intimately associated with limestone and other rocks which were undoubtedly sedimentary in their origin. But with the application of petrographical and chemical investigation to the problem, the sedimentary hypothesis was gradually abandoned—as regards the major part of the Laurentian complex—in favour of the igneous hypothesis, which is now generally accepted[1].

It has already been pointed out that along the northern border of the central belt of Laurentian gneisses, that is along the contact of the Laurentian axial belt and the Abitibi group, and within the axial belt near its northern margin, fine-grained rusty mica schists occur which have evidently resulted from the metamorphism of an arkose or related rock. Likewise, along the southern border of the central Laurentian gneissic complex, fine-grained rusty gneisses and amphibolite occur which are believed from their lithological character and chemical composition to be altered sediments, the former beng a mashed quartzite or arkose and the latter a metamorphosed limestone[2]. Thus it is probable that the proportion of sediments associated with the Laurentian is somewhat larger than is generally supposed, yet, the characteristics of the major part of the complex are such as to point conclusively to an igneous origin. The evidence upon which this conclusion is based may be summarized briefly as follows:—

(1.) The complex is largely composed of granite, diorite, granodiorite, and pegmatite, and hence is composed of rocks having the mineralogical and chemical composition and texture which belong to rocks of igneous origin.

(2.) Pegmatite constitutes a large and essential portion of the Laurentian complex and occurs not only in parallel bands but as dykes transverse to the banding.

(3.) The bands in the gneiss pinch out when followed along the strike, whereas sedimentary beds composing uniformly stratified series are generally continuous for considerable distances.

(4.) The extreme local heterogeneity of the Laurentian complex and the uniformity of this heterogeneity over many thousand square miles, is not characteristic of sedimentary rocks.

(5.) The dominant sediments which result from the decomposition of igneous rocks are argillaceous, and since the Laurentian banded gneiss has an areal extent in Canada of not less than 2,000,000 square miles, it might be expected that a considerable proportion of the complex would consist of slates, but on the contrary it is almost entirely composed of rocks approaching the composition of quartzite or arkose.

Origin of Banding, Folding, and Foliation.—Having assumed that the banded gneisses of the Laurentian complex are igneous in origin, it becomes necessary to frame an hypothesis which will account for the development of a banded, folded, and foliated structure in rocks which originally constituted a batholithic magmatic mass. A banded structure might develop in igneous rocks (1) by the flattening out of fragments of the invaded rock forming the roof of the batholith; (2) by *lit par lit* injection—that is, by the intrusion of dykes parallel the foliation of a gneiss; (3) by the deformation of (*a*) a heterogeneous magma during or immediately following its consolidation, or (*b*) a heterogeneous complex of igneous rocks in the zone of flowage long after consolidation.

The development of a banded structure along the contact of the Laurentian batholiths by the flattening out of xenoliths has been advocated by a number of

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[1] Adams, F. D., Jour. of Geo., vol. I, pp. 325–340, 1893.
Barlow, A. E., Annual Report, Geol. Surv., Can., 1897

[2] Adams, F. D., Amer. Jour. of Sci., vol. I, pp. 58–69, 1894.
Adams, F. D., Annual Report, Geol. Surv., Can., vol. VIII, 1895.
Adams and Barlow, Memoir No. 6, Geol. Surv., Dept. of Mines, Can., 1910.

Canadian geologists, and is undoubtedly an important mode of origin for the structure in some places, but this method alone cannot account for the banded structure of the Laurentian complex because the composition of the bands is for the most part different to that of the rocks constituting the batholithic roof[1].

A banded structure may originate by *lit par lit* injection, wherever a magma intrudes a rock which, because of its bedded or foliated structure, possesses a prominent cleavage. Thus, where the Laurentian rocks intrude the Pontiac schist the granite, aplite, and pegmatite occur, for the most part, as sheets or dykes paralleling the foliation. There are also some sharply-defined dykes of pegmatite and aplite in the gnessic complex which parallel the foliation and were probably intruded in this way, but it is scarcely possible that the banded structure of the Laurentian gneisses has originated to any great extent by *lit par lit* injection, for, if such were the case, the bands formed by intrusion (1) should be connected in places by dykes transverse to the foliation, (2) should be sharply defined on their contacts, and (3) should be continuous for considerable distances when followed along the strike. Instead of these features being present, the bands were never seen to connect transversely, the contacts of the bands are generally poorly defined the mineral grains interlocking across the line of junction, and the bands commonly pinch out in short distances when followed in the direction of their trend.

The third hypothesis to explain the origin of the banded gneisses has been divided into two subdivisions according to the time at which the deformation occurred, that is, according to whether it took place at the time of intrusion or long after consolidation. It has been pointed out in another place in this report, that the presence of conglomerates containing granite pebbles in the Abitibi group, which are themselves intruded by granite, indicates that an older granite occurs in the region and this might form a part of the Laurentian axial complex. In opposition to this supposition, it may be pointed out, however, that almost everywhere throughout the Laurentian banded gneisses, dykes of pegmatite occur transverse to the foliation and in all degrees of deformation, indicating that pegmatite dykes were being given off from the Laurentian complex while the banding was being developed. It might be possible that this pegmatite was derived from a magma intruded into the older granite, but there is no evidence anywhere in the whole Laurentian complex of two separate granite intrusions, and if such occurred, it has been entirely obliterated by deformation. Moreover, the banded gneisses were observed in contact with the Pontiac schist in which the pebbles of the older granite occur, for a distance of over 100 miles, and throughout the whole of this interval they are intrusive into the schist. It must be concluded, therefore, that if the banded gneisses include portions of an older granite, this granite, either by deep burial or by an accession of heat from the later intrusion, was reduced to such a plastic condition as to behave practically the same as an original cooling magma.

In order to establish the hypothesis that the Laurentian banded gneisses originated by the deformation of a heterogeneous magma during or immediately following its consolidation, it would be necessary to show (1) that the Laurentian complex was subject to deformation during and following its consolidation, and (2) that the complex was heterogeneous before the deformation began or before it was completed. In support of the first proposition, it may be pointed out that geological investigation throughout the world has shown that mountain chains are generally highly folded and that wherever mountains have been deeply denuded, batholithic masses of acidic rocks have been found at their core. Moreover, it has

[1] Lawson, A. C., Annual Report Geol. Surv., Can., vol. III, part I, p. 138F, 1887.
Adams, F. D., and Barlow, A. E., Memoir No. 6, Geol. Surv., Dept. of Mines, Can., 1910.
Miller, W. G., and Knight C., Annual Report, Bureau of Mines, Ont., vol. XX, pp. 280–284, 1911.

already been shown in previous sections of this report that the Laurentian banded gneisses occur in a central belt intervening between a northern and southern geological province in which sediments and volcanic flows predominate. It is concluded, therefore, that the Laurentian banded gneisses originally formed the core of a Pre-Cambrian mountain chain and constitute a geanticlinal axial belt intervening between geosynclines. And since mountain-building is accompanied by deformation, it follows that if the mountain-building deformation continued until the axial complex began to consolidate, the complex would also be deformed. That the deformation did continue after consolidation had begun, is demonstrated by the evidence of folding, foliation, granulation, and other dynamic features almost everywhere throughout the complex.

But in order that an igneous mass might assume a banded structure as a result of deformation, it would be necessary that the mass be heterogeneous before the deformation began or, at least, before it was completed. This might be demonstrated in the case of the Laurentian complex either indirectly by pointing out that plutonic igneous masses are generally heterogeneous[1], or more directly by making an examination of those areas of Laurentian which do not possess a banded or foliated structure to see if they are variable in composition from point to point.

Plutonic rocks, when examined over areas of considerable extent, are almost always found to be heterogeneous. This heterogeneity must obviously be due to either assimilation of foreign rock, or to differentiation within the magma itself. That assimilation occurred in the case of the Laurentian complex is evident from the occurrence of partially assimilated fragments of both the Abitibi group and the Grenville series along the batholithic border, but whether this process was of great importance or not, is unknown. It is also probable that basic and acidic aggregations and other variations were present in the Laurentian as in other plutonic masses, but it is doubtful whether all of these as developed in normal plutonic rocks would account for the excessive heterogeneity which would have to be present to result in such variability in composition as occurs in the Laurentian complex.

Throughout the northern geosynclinal belt formed by the rocks of the Abitibi group, small batholiths of granite occur which are presumably offsets from the main magmatic mass. These, because of their small size, would no doubt consolidate much more quickly than the larger central complex, so that, in them, we should expect to find the record of the early stages in the series of events which resulted in the development of the banded gneisses of the Laurentian complex. These batholiths consist largely of massive granite, but are exceedingly heterogeneous as shown by the following quotation describing their lithological character. 'The most prominent feature observed in making an examination of an exposure of these rocks is their excessive variability. In some places, a granite containing very little biotite may be seen to cut across another granite in which this mineral is more abundant, or a biotite granite may cut a hornblende granite in a similar manner. Very commonly long schlieren of granite rich in biotite are present, or the rock may have a banded appearance owing to variations in the amount of biotite'[2]. From this it seems probable that these small batholiths were subject to movements during their consolidation which, in some cases, dragged the viscous magma out into schlieren and, in other cases, broke up the magma after it had become solid so that the central magma of more acid composition flowed in to fill up the fractures. By this process of deformation during consolidation, a magmatic mass originally homogeneous might continue to become more and more heterogeneous as the kneading process continued, material of progressively more acid composition being squeezed out through fractures from the interior[3]. Not only would hetero-

[1] Teall, J. J., 'Origin of Banded Gneisses': Geol. Mag., pp. 484–492, vol. IV, 1887.
[2] Wilson, M. E., 'The Kewagama Lake Map-area': Geol. Surv., Dept. of Mines, Can., 1913.
[3] Harper, A., The natural history of Igneous Rocks: 1909.

geneity be developed by this process, but the variations in the magma would, as consolidation continued, be flattened out into thin lenses which, because of their different competency, would behave like sedimentary beds and assume a folded structure.

Conclusion.—In the preceding discussion of the origin of the banded gneisses of the Laurentian plateau, it was pointed out that the basement complex throughout northeastern Ontario and northern Quebec may be divided into three divisions, a northern belt consisting largely of sediments and volcanic flows (Abitibi group), a southern limestone belt (Grenville series), and an intermediate zone of Laurentian banded gneisses. It was also shown that the Laurentian gneisses were largely igneous in their origin, and from their geographical relationship to the Abitibi group and the Grenville series, it was inferred that they originally constituted the magmatic centre of a Pre-Cambrian mountain chain.

As regards the origin of the folded, banded, and foliated structure of the gneisses, it was suggested that these were all related to the Laurentian mountain-building deformation which acted upon the magmatic axial mass during its consolidation. While it was recognized that heterogeneity in a magma may be caused by the stoping off and partial assimilation of fragments of the batholithic roof, it was pointed out that another possible factor in bringing about the heterogeneity of the Laurentian complex was probably differentiation aided by deformation during consolidation. By this process, the magmatic mass was constantly being broken up, and the residual fluid magma of slightly different composition squeezed out to fill the fractures around the broken fragments. The variations in the complex produced in this way were then flattened out and crumpled into a folded structure resembling that assumed by folded sedimentary beds. During the final stages of deformation, the gneissic complex had evidently passed, for the most part, from the zone of flowage to the zone of fracture, for slickensiding between the bands, granulation, and fracture became the dominant deformational processes. It is also apparent from these conclusions that the foliation in the gneissic complex was developed by either recrystallization or granulation or both of these processes during or after the heterogeneous portions of the magma were flattened into bands, and that the Laurentian banded gneisses are, therefore, secondary in their origin.

This hypothesis that the banded gneisses of the Laurentian complex owe their origin to the deformation of a magmatic axial mountain mass during consolidation, is not only based on observation in the field where the various stages in the process can be recognized, but explains the heterogeneity, banding, foliation, folding, and other characteristic features of the gneissic complex more completely than any other hypothesis. Moreover, it postulates only such conditions as are generally accepted by geologists the world over, and assumes only such effects as must necessarily result wherever such conditions arise in the earth's crust.

COBALT SERIES.

No occurrences of the rocks of this series were seen in place in the whole region, but a large boulder of conglomerate, similar to that of the Cobalt series, was observed on the shore of Lake Matchimanitou so that it is possible that an outcrop of this member may occur somewhere in the district.

NIPISSING DIABASE.

Distribution.—In a number of localities throughout the northern part of the region traversed, the rocks of the Abitibi group and the Laurentian granite and gneiss are intruded by dykes of Nipissing diabase. The largest of these dykes observed was about 150 feet in width. It occurs on the west shore of the Bell

river a short distance north of the crossing of the National Transcontinental railway, and outcrops at intervals from this point northward for a distance of 5 miles. Two other dykes, over 100 feet in width, were observed, one on the west shore of Shabogama lake near its outlet, and the other on the north shore of Kamshigama lake. Other occurrences of Nipissing diabase were observed on the south shore of the southwest bay of Grand Lake Victoria, on the west shore of Simon lake, and on the hill in Senneterre township, known as Bell mountain. In all of the last-mentioned localities the dykes are narrow and outcrop for very short distances.

Lithological Character.—The Nipissing diabase, as it occurs in the centre of the larger dykes, has the appearance of a coarse gabbro, but, in the smaller dykes and along the margin of the larger ones, it is finer grained and distinctly ophitic. The original minerals composing the rock are labradorite, augite, ilmenite, biotite and quartz and feldspar in micropegmatitic intergrowths. The secondary minerals observed were chlorite, zoisite, epidote, sericite, and a carbonate.

PLEISTOCENE AND RECENT.

Glacial.—The Pre-Cambrian complex which forms the solid basement throughout the region is largely hidden beneath a mantle consisting of boulders, gravel, sand, and boulder clay. These materials are believed to have been laid down in association with a large continental glacier which covered northeastern Canada and the adjacent portions of United States, in the Pleistocene. They are, in part, unstratified and, in part, stratified. The deposits of the unassorted type are believed to have been deposited from the melting ice of the glacier directly, while the stratified deposits are believed to have been laid down indirectly from the glacier by the action of water, and are hence fluvioglacial in origin. The glacial material occurs scattered irregularly over the surface of the Pre-Cambrian complex, or in moraines. The fluvioglacial deposits may occur in elliptical-shaped hills —kames—or spread out over a wide area—outwash plains, or in long serpentine ridges—eskers.

Wherever the rocks of the Pre-Cambrian complex are exposed, their surface generally presents the polished and grooved appearance which results from glacial erosion. The ice movement, as indicated by the glacial striæ, was from a direction a few degrees east of north.

Post-Glacial.—Throughout the northern part of the region the glacial and fluvioglacial deposits are overlain by uniformly stratified clay and sand having a thickness, in places, of 15 to 20 feet. This stratified material consists of alternating beds of clay and silt, or of clay and sand, the beds ranging from one-half inch to 3 inches in thickness. The bedding of the stratified clay and sand near their point of contact with the underlying drift, or Pre-Cambrian rock surface, parallels the slope of the surface upon which it was deposited, but these undulations for the most part disappear within a few feet, the overlying beds assuming the flat-lying attitude which gives the surface of the clay belt its characteristic plain-like appearance.

It is believed that these uniformly stratified deposits were laid down from a huge temporary lake which covered a large part of northern Ontario and Quebec following the retreat of the last Labradorian ice sheet. In the region described in this report, the lake did not extend south of the height of land, but farther to the westward, the stratified clay occurs continuously southward as far as Lake Timiskaming, so that, for a time at least, the lake was connected with the St. Lawrence basin.

In two localities along the National Transcontinental railway near the crossing of the Bell river, the stratified clay has been crumpled, the crumpled zone having a width of from 1 to 2 feet. The beds of stratified clay both above and below

the crumpled zone are uniform, which indicates that the deformation occurred contemporaneously with deposition. It is difficult to explain how this peculiar folding was developed. The only plausible hypothesis which has occurred to the writer is, that it might be due to the thrust of shore ice. The basis for this hypothesis is the fact that in both cases the crumpled beds occur around the margin of hills of glacial drift which may have formed islands in the lake towards which the ice, formed during the winter, would exert a thrust.

Economic Geology.

In the section of this report describing the general geology of the region, it was pointed out that the basement of Pre-Cambrian rocks of northwestern Quebec may be divided geographically into three zones—a southern belt occupied by the rocks of the Grenville series, a northern belt underlain by the volcanic flows and sediments of the Abitibi group, and an intervening axial belt of banded gneisses. The experience of the past has shown that mineral deposits of economic value are more abundant in the rocks of the Abitibi group and Grenville series than in the central gneissic complex, and since the southern part of the area to which this report refers is underlain almost entirely by the banded gneisses, the most promising part of the region from an economic standpoint is to be found in the north.

In association with the rocks of the Abitibi group, there have been found auriferous quartz lodes of the Porcupine type, nickeliferous pyrrhotite such as that occurring at the Alexo mine near Kelso, Ontario, deposits of iron ore as at Michipicoten and Moose mountain, Ontario, and numerous occurrences of pyrite and chalcopyrite which, in places, may be of economic importance. In a few localities, dykes of pegmatite containing molybdenite, beryl, bismuth, and other minerals of the pegmatite association, also occur, which, while possibly not exceedingly valuable in themselves, are important in that they indicate the possibility of the presence of the more valuable minerals occurring in the same relationship. It is not improbable that deposits of the types mentioned in the foregoing list are present in the northern part of the region described in this report, but it happens that the rocks of the Abitibi group are entirely limited to the clay belt where the bed-rock is so poorly exposed that prospecting is exceedingly difficult.

The principal mineral occurrences seen during the season were sheets of muscovite in pegmatite; iron formation on Matchimanitou lake; and quartz veins both in the Laurentian gneissic complex and in the rocks of the Abitibi group. All of these deposits were, however, too limited in extent or too low in grade, to be commercially valuable at present.

Clay.

A sample of stratified clay taken from a cut along the National Transcontinental railway near the crossing of the Bell river, was submitted to Mr Joseph Keele for an examination of its ceramic qualities. The results of Mr. Keele's investigation are stated in the following report.

Report on a small sample of clay from the National Transcontinental railway near the crossing of the Bell river.

Description.—A Pleistocene clay, stratified and interlaminated with layers of silt, the whole being fine-grained and free from pebbles or coarse grit. It is non-calcareous. It takes 28 per cent of water for tempering, and works up to a fairly plastic mass, but is rather flabby, owing to the high percentage of silt.

The drying shrinkage was about 6·5 per cent.

It behaved as follows on burning:—

Cone	Fire shrinkage	Absorption	Colour
	%	%	
010	·5%	17·0%	Light red
06	·5%	16·0%	Red
03	4·0%	7·0%	Red
01	7·0%	1·5%	Dark red

This clay burns to a good dense steel hard body at cone 06 (1886° F). Burned at this temperature it would produce a good common red brick for building purposes. When burned to cone 03, or about 2000° F., it produces a very dense brick with low absorption which would be suitable for lining trunk sewers or other underground work. The clay is vitrified at cone 1, and the shrinkage excessive.

The clay will probably make a good field drain tile. It compares favourably with any of the clays of similar age found in the southern portions of the Province.

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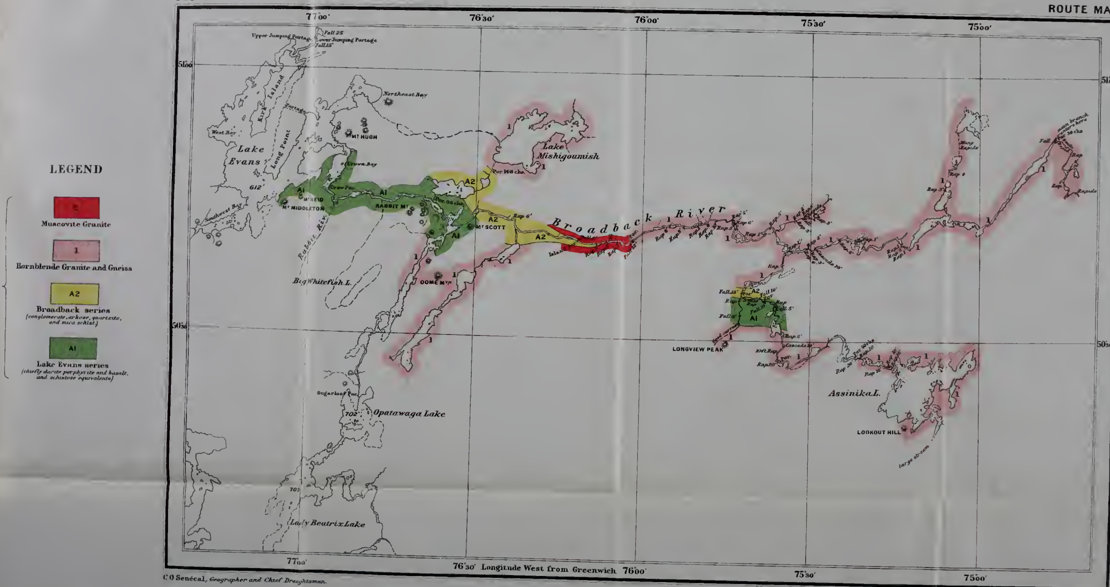
GEOLOGY

ROUTE MAP



C O Senécal, Geographer and Chief Draughtsman.

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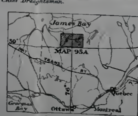

To accompany Summary Report, by H.C. Cooke, 1912.

MAP 95A
(Issued 1913)

BROADBACK RIVER
MISTASSINI TERRITORY
QUEBEC

Scale, 10 miles to 1 Inch

GEOLOGY
H.C. COOKE 1912

SURVEYS
R. BELL 1896
H C COOKE 1912
J.O FORTIN COMPILER

AN EXPLORATION OF THE HEADWATERS OF THE BROADBACK OR LITTLE NOTTAWAY RIVER, NORTHWESTERN QUEBEC.

(*H. C. Cooke*).

Introduction.

The writer spent the field season of 1912 on a reconnaissance of a hitherto unexplored area in northwestern Quebec, lying between longitude 74° 30′ W. and 76° 30′ W. and latitude 50° N. and 51° N. This district, about 120 miles in length by 70 in width, lies directly to the west of the south end of Lake Mistassini, and almost wholly within the basin of Broadback river. Former explorers reported the existence in this region of three large streams, the Mill, Broadback (Victoria), and Nipukatasi rivers, which coalesced at Lake Evans to form the Broadback or Little Nottaway river, emptying into James bay about 12 miles south of Rupert House. This report proved incorrect, however. Investigation showed the Mill and Nipukatasi rivers to be very small creeks emptying into wide riverlike inlets which, although currentless and choked with weed, otherwise resembled the mouths of large rivers. The only large stream of the district is the Victoria or Broadback as it is now called, a river about 700 feet in width by 4 to 6 feet in depth, and very swift. Several small streams fall into it before it enters Lake Evans; these tributaries are: the stream which rises in Lady Beatrix lake, and the Whitefish and Rabbit rivers. Its waters are also joined by the creek that drains Lake Mishagomish and empties into Northeast bay on Lake Evans.

The exploration was projected with the view of obtaining preliminary information as to the topography, regional geology, soil, mineral and timber resources of this region. As the area to be explored was large, and the time available for exploration limited, it was impossible to do more than investigate the principal watercourses and canoe routes. These routes were rapidly traversed and a track survey made, distance being determined by the use of the canoe log or by estimation with the eye, direction by the prismatic compass. Had discoveries warranted, more accurate surveys would have been undertaken; but as preliminary work showed that the district is in general underlain by gneisses, which are characteristically barren, such surveys were not made.

To determine the mineral possibilities of the district, as much time as possible was devoted to prospecting in areas of greenstones, schists, and clastics, presumably of Keewatin and Huronian age, and to panning the sands of the streams which flow through these areas.

Summary.

The rocks of the district consist, at the base, of a complex of basic schists, overlain by a sedimentary series of which the lowest member is a thick conglomerate and the uppermost a schist that is probably the metamorphosed equivalent of a shale. These formations have been folded and metamorphosed, and intruded by granites. Erosion has since removed the major part of the overlying rocks, and cut deep into the intrusive granites, so that the two first-named series now appear in two localities only. The rocks of the basal schist series are in places heavily impregnated with pyrite; but beyond this, little evidence of secondary mineralization could be detected. Veins are few and small, in so far as could be discovered, and filled chiefly with barren quartz.

Transportation.

The Grand Trunk Pacific railway now affords an easy means of access to the Natagagan and Bell rivers. Either of these streams is a good canoe route down to Lake Mattagami, 100 miles to the north. From this point a chain of lakes and streams, with few portages, extends east and north through the Gull lakes, Lady Beatrix lake, Opatawaga lake, and Kenoniska lake to the Broadback river. Altogether, the canoe trip is one of about 300 miles.

General Character of the District.

TOPOGRAPHY.

The region has considerable relief, especially in that part lying to the north of Broadback river above Lake Evans. Knobs and ridges of granite rise to heights of 500 or 600 feet above the level of the surrounding country, and the uniformity of their heights, together with the extent to which they are dissected, suggest some past period of peneplanation. The remainder of the country is plain-like, possibly the result of a second period of partial peneplanation; but accurate information on this point was not obtainable on account of the mantling of the surface by glacial drift. The drift is very thick over the entire district, and determines the minor features of the topography.

At the confluence of Broadback river and the stream flowing from Lady Beatrix lake to the south, the region has an average elevation of about 650 feet above sea-level; it rises rapidly eastwards to Lake Mistassini, 1200 feet above the sea. A rise of 550 feet thus occurs in a distance of 120 miles, or an average grade of 4½ feet per mile. As might be inferred from this, the rivers in their east-west courses are very rapid and rough. Falls, however, are not numerous, since, on account of the large amount of coarse glacial drift in the region, the streams are fairly well graded. This grading, while tending to lessen the number of falls and bad rapids, at the same time has substituted for them stretches of swift water, often miles in length, up which progress is exceedingly difficult.

FLORA AND FAUNA.

Around Kenoniska lake and for a distance of about 10 miles up Broadback river the original forest exists. This is here composed mainly of black spruce, the trees being usually 10 inches to a foot in diameter, but found also up to double this size. Jackpine is common in the sandy portions, and grows to about the same size as the spruce. Poplar and birch occur, but rarely over a foot in diameter, and so uncommon is the latter that the Indians have resorted to the use of canvas for making their canoes. No cedar was seen north of Middle Gull lake, 70 miles to the south of Broadback river. Farther up Broadback river the country was swept so thoroughly by fires 6 or 8 years ago as to be now almost bare for long distances, except for a few islands of spruce uninjured by the fire. Over these fire-swept areas the blueberry grows in great profusion, and second-growth jack-pine is beginning to spring up. Not until the most eastern point of traverse was reached did this burnt area come to an end.

Bears are unusually numerous in the district, and are almost the only large game animal found. Moose are practically unknown, and caribou not numerous.

General Geology.

GENERAL STATEMENT.

The geological succession and structure of this area is similar to that found in many portions of the 'Canadian shield.' The oldest group of rocks present is a schist complex, apparently similar petrographically and structurally to the Keewatin series of other districts. Above this lies, with unconformity, a series of clastic sediments, of which the finer-grained and more slaty members have likewise been converted into schists. The dips and strikes of the two series are similar. Batholiths of granite intrude both series alike. The series of Huronian sediments which in the Nipissing and Sudbury districts overlie the Laurentian unconformably are here absent; so also are the great intrusive sills of diabase and gabbro, of probably Keweenawan age, which appear in these districts. However, a few dykes of diabase are found, cutting all the formations mentioned.

Table of Formations.

Recent and Pleistocene	Coarse morainic deposits, sands, stratified clay in small amounts.
	Great unconformity.
Keweenawan (?)	Quartz diabase dykes.
	Intrusive contact.
	Muscovite granite.
	Intrusive contact.
	Biotite and hornblende granites and their gneissic equivalents.
	Intrusive contact.
Broadback series	Muscovite and biotite quartz schists, quartzite, arkose, conglomerate.
	Unconformity.
Lake Evans series	Various extrusive and intrusive rocks and their schistose equivalents.

DESCRIPTION OF FORMATIONS.

Lake Evans Series.—The rocks of this series are the oldest found in the district, and are petrographically and structurally similar to the Keewatin of other parts of the 'Canadian shield.' They consist chiefly of dacite porphyries and basalts, together with small amounts of very basic peridotites. Locally they have been converted into hornblende and chlorite schists; this is true more especially of the finer-grained portions of the flows, as the coarser parts have in general resisted the deforming influences more successfully. Two areas of the Lake Evans series were found in the district explored. The first, formerly mapped as Huronian, extends from the point of junction of the Broadback river and the stream draining Lady Beatrix lake, down Broadback river to Crow bay, Lake Evans. It forms an east-west belt of schists from 3 to 5 miles in width; the Broadback river occupies the middle of the belt, approximately paralleling the strike of the schists. The second area is found to the eastward, on the south branch of the Broadback river outcropping along the banks. The surrounding country is so heavily covered with sand that outcrops are rare away from the stream.

Broadback Series.—The Broadback series is a series of sediments lying above the Lake Evans series. It consists, from the bottom upwards, of conglomerate, arkose, quartzite, and mica schists. The composition of the mica schists suggests that they are the metamorphosed equivalent of a sandy shale. The beds have been folded, and now strike about N. 50° W. and dip steeply to the northeast, at angles varying from 45° to 60°. In spite of this deformation, however, the

conglomerate, arkose, and quartzite members have been but little affected, and are still massive and non-schistose; the shale member, on the contrary, has been very thoroughly converted into mica schist, probably because of its greater fineness of grain.

The conglomerate at the base of the series contains well-rounded pebbles of many different kinds; some five or six species of basic rocks, all of which could be matched with rocks now in place in the underlying Lake Evans series, were noted, together with at least three granites none of which were similar to any granite observed in the region. Many of the basic pebbles are schistose. In structure the conglomerate shows great irregularity. The material is poorly assorted and crudely banded, the bands irregular and lens-shaped, with wide variations in strike between different bands. It grades gradually downwards into a dark fine-grained mass of the same nature as the matrix of the conglomerate, with a few scattered pebbles.

Although it was impossible to observe the actual contact of the Broadback with the Lake Evans series, on account of the covering of drift, there seems little doubt that unconformity exists between the two. The occurrence of the conglomerate so near the contact would itself lead to the assumption that it is a basal conglomerate; the fact that the pebbles of the basic material can all be matched with rocks of the Lake Evans series in place indicates an erosion interval between the deposition of the two series; and the schistose nature of the pebbles, with their schistosity lying at all angles, is proof that deformation of the underlying series occurred before the upper was deposited.

No accurate measurements of the thickness of the conglomerate were taken, but if the outcrops have not been repeated by faulting it is great, in the neighbourhood of 1,000 feet. The great thickness, the change from the base upward from finer to coarser material, and the irregular assortment and banding, cross-bedding, and lens-like shape of the bands of pebbles, would all point to the deposition of the conglomerate, initially at least, as a sub-aerial rather than a marine formation.

It is impossible to place the age of this formation accurately at present beyond stating that it is younger than the Lake Evans series, which is probably of Keewatin age, and older than the hornblende granites, which intrude it. The hornblende granites are very similar in appearance to the ordinary Laurentian granites of other parts of northern Ontario and Quebec, and may be of the same age.

Hornblende Granites and Gneisses.—These coarse, pinkish granites and gneisses underlie the greater part of the area explored. In appearance they are very similar to the Laurentian granites and gneisses of the Cobalt and other districts to the south. They intrude the two previous series. Monadnocks of these rocks form most of the hills of the region.

Muscovite Granite.—Intrusive into all the previous formations is a muscovite granite, with white feldspars. It was found between the first and second falls on the Broadback river above its junction with the river flowing from Lady Beatrix lake, and also on Longview peak. As its intrusion seems to have been accomplished with but little disturbance of the surrounding rocks, and its intrusive relations with the Lake Evans and Broadback series are the same as those of the hornblende granites, the writer has tentatively classified it as a phase of the latter intrusion; but good evidence on this point was not obtained. No diabase dykes were found cutting this granite, but this is not regarded as decisive evidence of its age, as such dykes are very rare in the district in any case.

Keweenawan?—The previous formations, with the exception of the muscovite granite, are cut by a very few diabase dykes. These are petrographically similar to the quartz diabase of the Cobalt region, and may be of the same age.

Pleistocene.—The Pleistocene is represented by very heavy deposits of sand and gravel, presumably of glacial origin, so irregularly heaped together as to suggest terminal moraine. No evidences of stratification were seen except in one locality, where a small amount of stratified clay was found. Hills of sand and coarse gravel are frequently seen rising to heights of 300 feet or more above the surrounding country, and the gravels usually cover the sides of the granite hills of the district to a similar height.

Economic Geology.

Prospecting was carried on as far as time permitted throughout the areas of greenstones, schists, and clastics, but results were few. Small veinlets and stringers carrying quartz and pyrite, and a few larger veins or lenses of barren quartz up to 2 feet in width were the only discoveries. In a few places, notably on Broadback river about a mile below the mouth of Whitefish river, and on Storm lake near its western extremity, the Lake Evans schists were found to be heavily impregnated with pyrite, but assays of specimens from these impregnations gave no values. Panning for gold or diamonds was also carried on in the sands of the streams and streamlets passing over the Lake Evans-Broadback areas; but likewise with negative result.

THE TRENTON GROUP IN ONTARIO AND QUEBEC.

(*P. E. Raymond*)

Introduction.

The particular problem of the season was to arrive at a satisfactory correlation of the formations of Trenton age in Ontario and Quebec with each other and with the typical Trenton of New York. For this purpose, the writer and his assistant, E. J. Whittaker, visited central and northern New York, and then followed the formations west to Collingwood on Lake Huron, and east to Montreal and Quebec.

QUEBEC CITY AREA.

The section of the Trenton in the vicinity of Quebec was briefly described in my report of last year. At my request, Mr. Whittaker spent a few days this summer in collecting fossils and measuring a section at Point aux Trembles (Neuville), on the St. Lawrence, 23 miles west of Quebec. This section shows that the Trenton is thicker here than we had supposed, and, combined with the sections at Montmorency Falls, Lorette, and Chateau Richer, makes a complete exposition of the Trenton in this region. Numbers 6 to 4 in the following section represent the Trenton at Neuville, and 3 to 1 were taken at Lorette and Montmorency.

Composite Section.

(7). Interbedded shale and limestone, on a small creek about one mile west of Neuville. The limestone is in layers 2 to 5 inches thick, is fine-grained and clayey, and weathers yellow. The shales are brown to black, and carbonaceous. *Triarthrus becki* and *Climacograptus typicalis* are common in both shale and limestone. These beds are of Utica age, and 87 feet are exposed.

(6). Hard, thin-bedded limestone, light coloured and granular near the top, blue-grey and fine-grained below. The characteristic fossil is *Rafinesquina deltoidea*. *Triplecia nuclea* is very common, and the common fossils of the Trenton, such as *Plectambonites sericeus*, *Platystrophia lynx*, *Rafinesquina alternata*, *Calymene senaria*, and *Isotelus gigas*, are common. Thickness, 193 feet.

(5). Thin-bedded blue-grey limestone with thick shale partings. *Prasopora simulatrix* is very abundant at the base, and common all through the zone. *Triplecia nuclea* and *Trematis terminalis* are other common fossils, beside those mentioned above. Thickness, 117 feet.

(4). Dark limestone in beds 4 to 10 inches thick, with common Trenton fossils. Strata similar to those in zones 4 and 5 are exposed in the quarries at Beauport, and in the lower quarries at Chateau Richer. Thickness, 86 feet.

(3). Thick- and thin-bedded blue-black limestone with numerous fossils. Not exposed at Neuville, but well shown at the top of Montmorency falls, in the higher quarries at Chateau Richer and at Lorette. The characteristic fossil is *Cryptolithus tessellatus* (*Trinucleus concentricus*), and other common fossils are *Cheirocrinus gracilis*, *Trematis terminalis*, *Ceraurus pleurexanthemus*, and *Sinuites cancellatus*. Thickness, 50 feet.

(2). Thick-bedded dark grey limestone with numerous fossils, the characteristic one being *Trocholites canadensis*. Other common fossils are *Recepta-*

culites orientalis, *Tetradium fibratum*, *Lingula philomela*, *Plectoceras halli*, and *Calymene senaria*. This zone is exposed both on the St. Charles and on the Montmorency. About 20 feet thick.

(1). Resting on the gneiss at the falls of the St. Charles at Lorette, and above the bridge at the head of the falls at Montmorency, is a thin-bedded, blue-grey limestone with numerous fossils. At the contact with the gneiss is a small thickness, 6 inches to 2 feet, of fine-grained conglomerate, filling cracks and depressions in the gneiss. This fragmental material is fossiliferous, and there are many specimens of *Solenopora* still adhering to the Pre-Cambrian rock, in the position in which they grew. The characteristic fossil of this zone is *Parastrophia hemiplicata*, and other common forms are *Phragmolites compressus*, *Platystrophia lynx*, *Bumastus billingsi*, and *Ceraurus pleurexanthemus*. Thickness, 0 to 20 feet.

MONTREAL AREA.

At Montreal the lower part of the Trenton is well exposed in the extensive quarries north of St. Denis street in Mile End. The upper part is mostly concealed, though there are a few outcrops on the sides of Mount Royal. The Leray limestone is exposed in small abandoned quarries near the corner of Christopher Columbus and Bellechasse streets, and the contact with the Trenton may be seen in the vacant lot between Christopher Columbus and Normanville streets, east of Bellechasse street. The two large quarries north of Normanville street and west of the railway are in the lower Trenton, below the range of *Cryptolithus tessellatus*, while the upper layers in the quarry east of the tracks belong to the *Cryptolithus* zone. All the strata here have a gentle dip to the east, but are somewhat displaced by small faults, along some of which dykes are intruded.

The Leray rests on the Lowville, which is a light buff, pure limestone, full of *Tetradium cellulosum*. Only about 1 foot of the Lowville is exposed, and the thickness of the formation must be small, for the Chazy was seen in a trench on Christopher Columbus street less than 500 feet west of the outcrop of the Leray, and the Lowville thus could not be over 10 feet thick. The Leray is about 12 feet thick, and is like the Leray at St. Vincent de Paul, that is, it is of the type of the Leray of New York, with plates of black chert, and an abundance of large cephalopods, among them *Ormoceras tenuifilum*. The lower layers of the Trenton, when not weathered, are massive, nearly black, fine-grained limestone. On weathering they show a thinner bedding and shaly partings. Fossils are common in spots, but the quarries do not afford really good collecting places. *Parastrophia hemiplicata*, *Phragmolites compressus*, *Platystrophia lynx*, and *Calymene senaria* are found in the lowest layers, indicating that we have here, as at Quebec, the *Parastrophia* fauna at the base of the Trenton. Toward the top of the large quarry west of Quarry street, the *Parastophia* is associated with *Triplecia nuclea*, both being abundant.

Cryptolithus tessellatus is very abundant in the upper layers of the large quarry east of the railway tracks, but the greater part of the strata of this zone are concealed. As estimated from the dip, this zone would be about 50 feet thick. The *Prasopora* beds are encountered on Iberville street, one-half mile east of the large quarries just described. These beds are quarried to obtain stone for crushing, and consist of thin-bedded limestone with *Prasopora simulatrix*, *Platystrophia lynx*, *Dinorthis meedsi* and numerous other fossils. About 25 feet of these beds are exposed, and the higher strata farther east are either unfossiliferous or are concealed.

CHAMPLAIN VALLEY AREA.

The lower Trenton of the Champlain valley shows the same faunal zones

that are seen at Quebec and Montreal. The *Parastrophia* fauna occupies the lower 45 feet of the Trenton at Crown point, while the *Cryptolithus* fauna occurs in the succeeding 50 feet. The *Prasopora* strata are best exposed farther north on Crab island, near Plattsburgh. There are no continuous sections of the Trenton in this area, but the *Rafinesquina deltoidea* fauna seems to be absent, and the strata above the *Prasopora* zone consist of shale and limestone interbedded, with a graptolite fauna. South from the Champlain valley the lower zones, particularly that with *Cryptolithus*, can be followed around into the Mohawk valley, and thence to Newport, only 14 miles from the type-section of the Trenton at Trenton Falls, N. Y.

TRENTON FALLS REGION.

The section at Trenton Falls is unfortunately incomplete, as it does not extend down to the Black river, the lower beds of the Trenton being concealed. A few specimens of *Cryptolithus* have, however, been found in the very lowest beds exposed there, thus indicating that the strata of that zone are present, although below water level. In the following composite section, compiled from the work of White, Prosser and Cumings, and Raymond, zones 8 to 4 are found in the gorge at Trenton Falls, as are also the very uppermost layers of 3, and zones 3 to 1 are exposed on Rathbone brook at Newport.

Composite Section.

(9). Thin-bedded black and brown carbonaceous shale with *Triarthrus becki* and graptolites. The contact with the limestone below is sharply defined, and there are no transitional beds. Utica shale. Thickness, about 300 feet.

(8). Light grey, coarse-grained limestone, with *Rafinesquina deltoidea*, *Hormotoma trentonensis*, and other fossils. Thickness, 26 feet.

(7). Thin-bedded blue limestone with shaly partings. This zone contains many fossils, *Rafinesquina deltoidea* being the common and characteristic one. Thickness, 92 feet.

(6). Thin-bedded blue limestone with thick shaly partings. *Prasopora simulatrix* is common all through but especially abundant at the base. Thickness, 100 feet.

(5). Thin and thick beds of limestone, mostly dark and fine-grained, *Diplograptus amplexicaulis* is a common fossil. Thickness, 35 feet.

(4). Thin-bedded dark limestone, with *Triplecia extans*, *Dalmanella rogata*, etc. Thickness, 20 feet.

(3). Thin-bedded dark limestone, alternating with thick coarse-grained beds. *Cryptolithus tessellatus* is the common fossil. *Trematis terminalis*, *Platystrophia lynx*, *Calymene senaria*, and many other fossils are present. Thickness, 41 feet.

(2). Thin-bedded grey limestone with an abundance of *Dalmanella rogata*, and some other fossils. Thickness, 32 feet.

(1). Dark grey, lumpy limestone with some chert. There is a very large fauna, including *Gonioceras anceps* and many trilobites. Leray-Black river.

WATERTOWN AREA.

From Trenton Falls the Trenton can be followed northwest along the valley of the Black river and its tributaries until it disappears under the waters of Lake Ontario. On the Canadian side of the lake it appears again all along the shore from just west of Kingston to Cobourg, and can be traced to Collingwood on Georgian bay. Very complete sections can be seen in the Black River valley in

New York state. The only massive limestone in the section at Trenton Falls is in the highest zone, which is only 26 feet in thickness. Professor Miller has, however, pointed out the important fact that as one goes northwest from Trenton Falls, the thickness of the massive beds at the top of the section increases, and this led the writer to suspect that the sections in that region were similar to the Canadian ones. We, therefore, visited some of the most continuous sections south and southeast of Watertown, and found the one on Roaring Run at East Martinsburg particularly complete and interesting

The cherty Leray beds of the Black river form the top of the first escarpment west of the town, at the upper end of the lowest of the gorges on Roaring Run. A few rods upstream from the outcrop of the Leray the base of the Trenton is encountered. The lowest beds of this formation consist of thin-bedded limestone with an abundance of fossils, *Triplecia extans* being the most abundant and characteristic. *Dalmanella rogata*, *Platystrophia lynx*, *Orthis tricenaria*, and *Calymene senaria* are other common fossils. This fauna is the same as that of No. 4 of the Trenton Falls-Newport section given above, and it also distinctly suggests the fauna of the lowest Trenton beds at Rockland near the city of Ottawa, and the lowest Trenton of central Ontario. It will be noted that *Cryptolithus* is entirely absent. The strata of this lowest zone were not fully exposed, but seemed to be about 25 feet in thickness. Continuing up the stream to the lower end of the second gorge, the lowest layers there were found to contain *Ceraurus dentatus*, *Subulites elongatus*, *Orthis tricenaria*, *Strophomena incurvata*, and other fossils which indicate the same general fauna as the crinoid beds at Ottawa or in central Ontario. There seemed to be about 30 feet of these beds, and they were followed by thin-bedded layers of dark limestone which were interstratified with shale beds 1 to 3 inches thick. These layers were full of *Prasopora* and the common Trenton fossils. They make the main falls in this gorge, and seem to be about 75 to 100 feet thick. Emerging from this gorge and crossing the road on the second bench, one comes, at some distance west of the road, upon heavy-bedded, dark limestone containing *Rafinesquina deltoidea* and *Hormotoma trentonensis*. These beds are not well exposed along the stream, but may be seen along the roads and in old quarries on the hill about the town of Martinsburg. The lithology and fauna of these beds is the same as that of the highest Trenton beds, known as the 'Sponge beds,' at Ottawa. These strata are at least 120 feet thick, and probably more, and form the highest beds of the Trenton here, being succeeded by the dark soft shales of the Utica. These same beds were seen again at and near Adams and Ellisburg, southwest from Watertown, and in each case they formed the highest beds of the Trenton, and had the same lithology and carried the same fauna as the highest of the Trenton strata at Ottawa.

PICTON AREA.

From Watertown we went into Ontario, and visited a large number of exposures of the Trenton between Picton in Prince Edward county and Collingwood on Lake Huron. At Picton the upper beds of the Trenton cap most of the bluffs near the town, and Mr. Whittaker spent some time in collecting in that region. He reports the following section near the cemetery south of the town:—

Section near Picton.

(5). Heavy-bedded, rubbly weathering limestone forming the top of the bluff. Thickness, 14 feet.

(4). Similar limestone with a great abundance of gastropods, notably *Hormotoma trentonensis*, *Fusispira subfusiformis*, and *Trochonema umbilicatum*. Only partially exposed. Thickness, 74 feet.

(3). Rather more thin-bedded and shaly limestone with comparatively few fossils. *Rafinesquina deltoidea* present. Exposed in quarry on hillside. Thickness, 49 feet.

(2). Thin, shaly limestone with *Prasopora simulatrix*, *Diplograptus amplexicaulis*, and *Rhynchotrema inæquivalve*. Probably the upper beds of the *Prasopora* zone, although a similar zone is known in the lower part of the *Hormotoma* beds. Thickness, 12 feet.

(1). Strata mostly concealed to the lake. Thickness, 70 feet.

The upper beds are seen all over the southern part of Prince Edward county, are exposed farther west at Cobourg, and disappear under the Collingwood formation near Whitby. The very highest layers of these same beds outcrop on the lake shore at Collingwood.

CENTRAL ONTARIO AREA.

The lower part of the Trenton in central Ontario has been described by Mr. W. A. Johnston in the Summary Reports of the Director of the Geological Survey for 1910 and 1911. Large collections of fossils made this year at a number of places between Belleville and Trenton on Lake Ontario and Lake Simcoe show that the slope of the land corresponds so nearly to the dip of the strata that the middle or *Prasopora* zone of the Trenton is exposed over large areas, and the sections along the rivers are almost worthless for giving measurements of thickness. Throughout the whole area the Trenton seems to be divisible into four principal faunal zones, but we have very little data as to the thickness of the two upper zones, which together probably make up four-fifths of the total. The zones, with their approximate thicknesses, are as follows:—

(4). *Hormotoma trentonensis* zone. Thick-bedded, impure dark limestone which weathers to a rubbly mass. The principal fossils are *Hormotoma trentonensis*, *Fusispira subfusiformis*, *Trochonemas*, and *Liospiras*. The lower part constitutes a sub-zone of considerable thickness, characterized by *Rafinesquina deltoidea*. This species is found in the uper part of the zone also, but its place there is largely taken by *Strophomena trilobata*. Thickness, 150 to 200 feet.

(3). *Prasopora* zone. Rather thin-bedded limestone, sometimes light grey and coarse-grained, with thick shaly partings. The fossils are very numerous and varied. *Prasopora simulatrix*, *Dinorthis pectinella*, *Rhynchotrema inæquivalve*, and *Platystrophia lynx* are always abundant and usually present at every outcrop. As a sub-zone in these beds, there occurs the fauna with *Agelacrinites billingsi* and crinoids, suggestive of the Cystid beds at Ottawa. Total thickness, about 150 feet.

(2). Crinoid zone. Light grey, coarse-grained limestone with shale partings. Lithologically much like the last, but not usually so thin-bedded or so shaly. Characterized by numerous crinoids and cystids. Thickness, about 35 feet.

(1). *Dalmanella* zone. Thick-bedded dark grey fine-grained limestone with a little shale. The fauna contains many survivors of Black River times but includes *Calymene senaria*, *Platystrophia lynx*, and other fossils which are believed to be of Trenton age. *Dalmanella rogata* is especially abundant, though not by any means confined to this zone. Thickness, about 40 feet.

SUMMARY.

From the above descriptions and sections, it will be seen that the Trenton at Quebec and Montreal are in essential agreement with the typical Trenton at Trenton falls, and that the *Cryptolithus* zone is immediately beneath the lowest strata at Trenton falls. The greater part of the fauna in this whole region east of Trenton

falls is made up of long ranging and cosmopolitan species, and there are no strongly marked sub-zones. This lack of distinctive species makes it difficult to characterize the typical Trenton fauna, for if we enumerate the common fossils, *Dalmanella rogata*, *Plectambonites sericeus*, *Platystrophia lynx*, *Zygospira recurvirostris*, *Calymene senaria*, *Ceraurus pleurexanthemus*, *Isotelus gigas*, etcetera, we are naming fossils, which, from their long range, afford little basis for correlation. In each zone there are, however, a few common fossils which have a restricted range. The *Prasopora* zone is less satisfactorily characterized faunally than any of the others, most of its common species having a long range. *Prasopora simulatrix* itself seems to range from bottom to top of the Trenton, so that the presence of a single specimen or of a few specimens of this species does not necessarily indicate the particular part of the Trenton which is here called the *Prasopora* zone. But the presence in thin-bedded shaly limestone of vast numbers of hemispheric bryozoa is usually a safe indication of the zone in question.

West from Trenton falls the lower zones with *Cryptolithus* and *Parastrophia*, zones which are very prominent in the eastern sections, disappear, and the strata which are just below the *Prasopora* zone at Trenton falls increase in thickness and become more fossiliferous. At the same time, the strata above the *Prasopora* beds also increase in thickness, and the *Hormotoma trentonensis* zone is added to the upper part of the section, so that the section in central Ontario is really equivalent to the Trenton Falls section without the Newport section, and plus the higher beds so well developed around Picton and Ottawa. There are many local developments and variations in the faunas in the various zones, and there is a much greater variety in the fossils found in the Trenton of Ontario than in the Trenton of Trenton Falls. These differences are frequently as much due to the changes in lithology, the effect and the amount of weathering, the nature and extent of the exposures, and the chances of collecting, as to actual differences in the constitution of the fauna. Thus there is much greater opportunity to find crinoids on the canal dumps at Kirkfield than in the vertical cliffs of what seem to be the same beds at Roaring Run. One real difference, however, is the great abundance of *Triplecia nuclea* and *Trematis terminalis* throughout the whole section near Quebec, and their total absence from the central Ontario region. In central Ontario the strata throughout the section tend to be light coloured and coarse-grained, becoming lighter the farther west one goes, while in New York and Quebec, the limestone is fine-grained and dark.

The probable correlations are seen at a glance in the accompanying table, in which names have been given to the formations characterized by the principal sub-faunas.

Tabular View of the Middle Ordovician Formations of Ontario, New York, and Quebec.

	Faunal zones	Ottawa	Central Ontario	Trenton Falls and Rathbone brook	Montreal	Quebec	Formation names
Utica Group	Climacograptus typicalis	Abt. 75 ft.	Abt. 60 ft.	300 ft.	Present	Abt. 300 ft.	Utica
	Ogygites Canadensis	30 ft.	25 ft.	Absent	Absent	Absent	Collingwood
Trenton Group	Fusispira and Hormotoma	125 ft. +	Abt. 200 ft.	Absent	Unknown	Absent	Upper Picton
	Rafinesquina deltoidea			118 ft.	Unknown	200 ft.	Lower Picton
	Prasopora	100 ft. +	Abt. 150 ft.	100 ft.	Present	200 ft.	Trenton
	Crinoid	100 ft.?	35 ft.	Absent?	Absent	Absent	Hull
	Triplecia extans	40 ft.	40 ft.	55 ft.	Unknown	Unknown	Rockland
	Cryptolithus	Absent	Absent	41 ft.	50 ft.	50 ft.	Glens Falls
	Parastrophia	Absent	Absent	32 ft.	50 ft.	40 ft.	
Black River Group	Gonioceras anceps	40 ft.	30 ft.	25 ft.	15 ft.	Absent	Leray
	Tetradium cellulosum	15 ft.	10 ft.	26 ft.	10 ft.	Absent	,, Lowville
	Onchometopus simplex	50 ft.	50 ft.	Absent	Absent	Absent	Upper Pamelia
	Fauna variable	65 ft.	Absent	Absent	Absent	Absent	Lower Pamelia
Sub-formation		Upper Chazy.	Gneiss	Upper Cambrian	Upper Chazy	Gneiss	

Some of the formation names in the last column of the table are new. The name Glens Falls was proposed by Ruedemann for the formation which is at the base of the Trenton through the St. Lawrence and Champlain and Mohawk valleys. It is from 75 to 100 feet thick, and is characterized by two faunas, that with *Cryptolithus* above and the one with *Parastrophia hemiplicata* below. The guide fossils are common and easily recognized. The name Rockland is proposed for the lowest Trenton beds in the Ottawa valley and in central Ontario, and the name is from the town of Rockland on the Ottawa river, about 30 miles east of Ottawa. The name Hull is proposed for the strata which at Ottawa, Belleville, and in central Ontario, carry the well-known crinoid fauna. The name is from the city of Hull across the Ottawa river from Ottawa. The name Trenton is provisionally used for the thin-bedded limestone and shale characterized by a great abundance of hemispheric bryozoans. The name Picton is derived from the town of that name in Prince Edward county, and is applied to the heavy-bedded limestones with the gastropod fauna, and the under-lying, thinner-bedded limestone with *Rafinesquina deltoidea*.

THE UPPER LIMIT OF THE TRENTON.

In the region west from Trenton Falls there is never any trouble in locating the boundary between the Trenton and the overlying formation. At Trenton Falls the actual contact is not seen, but a short distance north of that place the dark, thin-bedded Utica shale rests directly on the heavy-bedded grey Trenton limestone. In Ontario, a thin formation, the Collingwood, intervenes between the Trenton and the true Utica. The Collingwood consists of alternating beds of limestone and shale, but its characteristic fossil, *Ogygites canadensis*, is so abundant, that the dividing line is easily recognized. East of Trenton Falls the case is quite different, for the Trenton itself is largely shale, as seems to be the case at Montreal, and it is seldom possible to draw a line between the two formations with certainty. In the region of Quebec, however, it seems reasonably certain that all the deposits of Trenton age are limestone, and that the first appearance of shale with *Triarthrus becki* and graptolites is a true indication of the Utica, even though there is a zone in which there is a transition lithologically from the limestone of the Trenton to the shale of the Utica. The presence of *Rafinesquina deltoidea* in the upper part of the Neuville section indicates that the upper strata there are of the same age as the upper strata at Trenton falls.

LOWER LIMIT OF THE TRENTON.

Unfortunately the section at the type locality is incomplete at the lower end, and the strata there cannot be seen to rest on the Black River. The typical exposure of the Black River is at Watertown, N. Y., and it is known that between the lowest strata exposed in the section at Trenton falls and the top of the Black River as exposed at Watertown, there are a number of feet of limestone strata. The disposition of these strata is a matter of dispute, some referring them to the Black River and others to the Trenton. The whole question, however, seems to hinge upon the correlation of the members of the Black River, and it will be necessary to discuss this point briefly.

In the vicinity of Watertown the Black River group consists of four members, the highest of which is the Watertown limestone. This limestone is only 8½ feet thick, but is very massive, and contains a remarkable number of large specimens of *Gonioceras anceps*, *Hormoceras tenuifilum*, and other cephalopods, as well as *Columnaria halli*. Beneath this formation is another thin formation, the Leray,

which consists of layers of limestone from 1 to 3 feet thick. The Leray contains a great amount of black chert in large flat plates, and bears a large fauna in which mollusca and trilobites predominate. *Goniceras anceps*, *Hormoceras tenuifilum*, and *Columnaria halli* are present, although not so common as in the layers above. This formation is 12 feet thick at Watertown. These two formations really form a unit in lithology and fauna, but in attempting to trace them away from the immediate vicinity of Watertown, the lower member with the chert and the large fauna can be followed long distances east and west, but the upper member evidently represents very local conditions, for it cannot be recognized outside the typical area. The Leray, when followed west through Ontario, remains a heavy-bedded cherty limestone, but becomes constantly lighter in colour and coarser-grained. It retains a large part of its characteristic fauna, except that in places in central Ontario, *Gonioceras anceps* seems to be absent, although present again in the Manitoulin islands, where it has been found by Dr. Foerste during the last two seasons.

When followed southeast from Watertown, the Leray persists as a dark, massive, cherty limestone, though it becomes progressively thinner. It is present in large quarries and along the railway near Newport at the lower end of the Rathbone Brook section, and it is there 32 feet below the base of the *Cryptolithus* zone, and about 70 feet below strata corresponding to the lowest layers at Trenton falls. On Lake Champlain and at Montreal a similar limestone with much the same fauna occurs about 50 feet below the *Cryptolithus* zone, and probably represents the same horizon. As before stated, the cherty Leray is succeeded on Roaring Run, north of Trenton falls, by strata equivalent to the lowest strata exposed at Trenton falls (*Triplecia extans* fauna), so it is evident that somewhere between Roaring Run and Rathbone brook, some 70 feet of strata, the upper 40 feet of which contain the *Cryptolithus* fauna, have been intercalated between the *Triplecia* beds and the Leray. Whether these strata belong to the Trenton or to the Black River must be decided largely by the affinities of the fauna. It is readily seen that they are not faunally allied to the Watertown limestone which overlies the Leray at Watertown. There is no lithological break between the *Cryptolithus* beds and the strata above them, and the fossils accompanying *Cryptolithus* are mostly species which occur in the strata above rather than in the Leray. On the other hand, there is a distinct change in lithology between the Leray and the strata immediately above it, and a more striking change in the fauna. While a number of species which pass from the Leray into the beds above can be cited, still it must be pointed out that there is a distinct change in the facies of the fauna. The Lowville, Leray, and Watertown faunas are predominantly molluscan in composition, cephalopods, gastropods, and pelecypods being the most numerous fossils. In all the post-Leray faunas up to the *Hormotoma trentonensis* beds, brachiopods are most numerous, and gastropods and pelecypods relatively, and often actually, few and unimportant. And this is not due to lithology, for there is about the same lime content in all these formations. The writer, therefore, believes that all the beds above the Leray-Watertown formations belong to the Trenton, and in practice, has found that *Calymene*, *Platystrophia*, and *Parastrophia* are common fossils which do not occur in the Black River, and that, therefore, indicate the Trenton. On the other side, *Gonioceras anceps*, *Hormoceras tenuifilum*, and *Dalmanella gibbosa* are fairly common species of the Black River which do not range so high as the Trenton. *Columnaria halli* is also a pretty safe indicator of the Black River, as I have known of only one or two cases where it has been found in the Trenton.

INVESTIGATION OF CLAY RESOURCES OF QUEBEC.

(Joseph Keele)

Introduction.

The laboratory work on the samples of clays and shales, collected in the western provinces and New Brunswick during 1911, was finished by the end of April. Over 100 samples were submitted to a complete series of physical tests. The greater part of these tests, with descriptions of the deposits from which they were collected, form the second part of a series of reports on clay and shale deposits of the western provinces.

A preliminary report on the clay and shale deposits of New Brunswick is in preparation. In addition to the regular work of testing the materials collected in the field, a large number of small samples from various sources were sent to the office for examination. These have been reported on in more or less detail, according to their importance.

The field work for the season of 1912 was devoted mainly to an examination of the clay and shale deposits of the Province of Quebec, but a short time was also taken up in similar work in New Brunswick. Owing to the incessant rain during the summer, the season was unfavourable to an examination of deposits of this nature, so that the progress made was not very great.

The portion of the Province of Quebec which was examined this season, was confined to the valley of the St. Lawrence river between the cities of Montreal and Quebec.

The materials of value to the clayworker, found in this area, are limited to the surface clays, the shales of the so-called Utica-Lorraine and Medina formations, and, possibly to a small extent, the Sillery and Levis formations.

Although there are large areas of slates and schists in the Eastern Townships, and in the vicinity of the city of Quebec, these materials are of no value to the clayworker, as they are not plastic. While sometimes resembling shales, both in structure and colour, they cannot be worked into shapes when finely ground and mixed with water, as it is possible to do with shales.

Unconsolidated Deposits.

A varying thickness of sands, gravels, and clays, of recent origin, is spread over the greater part of the surface of the St. Lawrence valley, between the Ontario boundary line, and the city of Quebec. The clays are of two general types: (1) boulder clays—deposits of glacial origin, generally mixtures of rounded stones of all sizes, with a gritty plastic clay; (2) clays either stratified or massive, free from pebbles, varying in quality from highly plastic, stiff varieties to lean, sandy ones.

The boulder clays are mostly found directly overlying bed-rock, and are not used in the brickmaking industry, owing to the fact that expensive grinding machinery is necessary to pulverize the stony portion of the deposit.

The brickmakers' material is selected from the clays of the second type, which may either occur overlying the boulder clay, or beds of gravel or sand, or resting directly on bed-rock. The greater part of these clays was deposited during a period when the valley of the St. Lawrence was depressed to such an

extent that the sea invaded it with a depth, in places, of 600 feet. During this period more than 100 feet of clay was deposited in places in the valley bottom, but most of it has since been removed by erosion. The clay, however, still forms a sheet of considerable extent on both sides of the St. Lawrence river, but is often concealed by extensive patches of sand.

While the clay is mostly of marine origin, and was deposited subsequently to the general glaciation of the region, there are also present older beds of clay as shown by the occasional presence of boulder clay overlying stratified clay, and a rather gritty, stiff plastic clay, free from large pebbles. Only a very brief description of the useful clays found in the unconsolidated deposits, under the name 'surface clays,' can be given in this report.

SURFACE CLAYS.

The surface clays are abundant on both sides of the river in the St. Lawrence valley, btween the Ontario boundary line and the city of Quebec. Over large areas they form the soil upon which crops are grown, but at many points they are covered by layers of sand or gravel, of such a thickness that they are inaccessible to the clayworkers.

While at some places the surface clays are situated more conveniently to markets and transportation facilities than at others, yet they are so wide-spread that they cannot be monopolized or cannot be exhausted.

The surface clays are of recent origin, and are unconsolidated. In structure, they generally show a succession of thin layers of a fairly uniform kind of sediment. These sediments are supposed to have been laid down on the bottom of an arm of the sea which invaded the valley during its submergence at the close of the Glacial period.

The term Leda clay has been applied to the surface clay of this part of the St. Lawrence valley from the fact that it contains the shells of *Leda glacialis*. As these shells only occur sparingly, and as there is evidently more than one type of clay present in the valley, the name Leda clay is withheld in the event of a more extended examination showing the possibility of a classification of them.

The clays are generally grey in colour, sometimes slightly calcareous, and although free from pebbles, are liable to contain small flattened and hardened concretions in some localities.

The upper part of the clay is oxidized to a rusty or brownish colour, but below this zone the clay is uniformly of a lead grey colour. The upper part is the most plastic, and works better for various uses, the lower part is silty, and works up in a rather flabby body when wetted. Both kinds are mixed together in brickmaking, and generally some sand is added to the mixture.

The uses of these clays in the clayworking industry are limited to the manufacture of common brick—made by the soft mud process—drain tile, and terra-cotta lumber. They are not suitable for the manufacture of vitrified wares, as they soften at too low a temperature.

The clays all burn to a red colour. Common brick are made at a number of localities in the Province, but the chief centre, where the largest number of individual plants are assembled, is at St. Jean Deschaillons, on the St. Lawrence river. One of the best sections of recent clays and sands in the Province is exposed in the bank of the river at this locality. The lowest portion of the section consists of about 20 feet of yellow stratified sands. From 50 to 75 feet of clay overlies the bottom sand. The clay is brown or dark red in the upper portion, and lead grey in colour below. This deposit is built up of layers of clay, about half an inch in thickness, separated by thin films of silt. No boulders, pebbles, or concretions were observed in this portion of the deposit.

The clay is overlain by 20 or 30 feet of sand, gravel, and boulders.

A large quantity of common brick, for building purposes, is made annually in a number of works, situated on the narrow strip of ground between the base of the high bank and the margin of the river. The greater part of the brick produced here is shipped in schooners to Montreal.

Bed-rock Formations.

The bed-rock formations of the St. Lawrence valley, in which materials of value to the clayworker may be found, are confined chiefly to the following formations of early Palæozoic age:—

Silurian	Medina
Ordovician	Utica-Lorraine Levis Sillery

With the exception of one known occurrence of kaolin, or china-clay, and, probably, some feldspar deposits, the Pre-Cambrian rocks which form the northern rim of the St. Lawrence valley are devoid of material used in the clayworking industry.

The later Palæozoic rocks, such as the Carboniferous formation, which elsewhere often contains high grade clays, are absent in this portion of Canada. No traces of Mesozoic formations have been found in the region.

A vestige of what is supposed to belong to the Tertiary was found in the Chaudière valley, during gold mining operations. It consisted of some thin beds of yellow clay and gravel, underlying Glacial drift. The clay member of the formation is inaccessible at that locality, and has not been found elsewhere.

MEDINA SHALES.

The shales of the Medina formation, which overlie the Lorraine shales, belong to the lowest member of the Silurian. These shales are of a prevailing dark red colour, interbedded with sandstones. The formation as a whole is very friable and easily eroded when exposed to weathering, or glaciation. Its distribution in the Province of Quebec is confined to three small patches on the south side of the St. Lawrence, about midway between Montreal and Quebec.

Workable deposits of Medina shales occur at St. Monique on the Nicolet river, near the railway bridge on the Becancour river, and on the road half a mile east of St. Gregoire.

The Medina shales were uncovered during the construction of the Lotbinière and Megantic railway between Ville Roy and St. Philomene. Although these shales are very gritty they work up into a fairly plastic body, and burn to a rich red, strong brick. They may also be suitable for fireproofing.

UTICA-LORRAINE SHALES.

The ancient sediments comprising the Utica and Lorraine formations are of Ordovician age. The areas in the St. Lawrence valley supposed to be underlain by them, are indicated on the published general geological sheets of the region.

The separation of these two formations in the field was based on their fossil contents, but the sedimentary beds in both are of almost precisely similar character and appearance. In general, it may be stated that the Lorraine shales are light grey in colour, rather gritty in texture, and frequently contain irregular thin

sandstone layers, while the Utica shale is of dark grey colour, finer in texture, and has a more uniformly shaly structure than the Lorraine. As this general statement does not always apply, the two formations will be grouped together, under the compound name 'Utica-Lorraine,' in describing their economic value.

These shales are at present used for brickmaking at two localities in the Province of Quebec, one group of plants being situated to supply the market at Montreal, and the other near the city of Quebec.

The shales burn to a good, hard, dense, red body at fairly low temperatures, and make a much stronger brick than those generally produced from the surface clays.

The geological maps show several large areas of Utica-Lorraine shales occurring on both sides of the St. Lawrence river between Montreal and Quebec. As the greater part of these areas are covered with a mantle of unconsolidated materials —sand, gravel, or clay—the character of the bed-rock that underlies these materials is assumed from occasional exposures of shales seen in banks of streams or taken from deep wells. Where the overburden of loose material is thick, the shales underlying them are not accessible to the clayworker, but he must look for them where they occur at the surface or only a few feet beneath it. In some cases the upper part of the shale is softened by weathering, into a stiff brownish clay, which is highly plastic, and hard to work when used alone. This clay is entirely different in character from the Leda, and allied surface clays.

The weathered shale is found useful to mix with the hard shale found below it, as a mixture is then obtained having the necessary plasticity for good working in clay machinery, which the harder shale alone often lacks to some extent.

SILLERY AND LEVIS FORMATIONS.

A large proportion of beds, having a shaly structure, occur in the rocks which go to make up these formations. They are exposed for several miles along the banks of the St. Lawrence river, in the vicinity of the city of Quebec, and the town of Levis.

The shales of these formations have been much more highly altered and hardened than those of the Utica-Lorraine, so that they are mostly of no value in the clayworking industry. In two localities, however, shale beds were seen in these formations which might be utilized, one occurring near Ruel siding, at the east end of Levis, the other being near Sillery.

The Levis shale at Ruel siding is brownish, rather hard and splintery in character, but when finely ground and tempered with water, has some plasticity. It burns to a good, strong, dense, red body at 2,000°F. and could probably be used for wire cut, or dry-pressed bricks.

The Sillery shale, referred to, is exposed on the line of the National Transcontinental railway about 1½ miles west of Sillery church. It is softened to a considerable depth by weathering, the natural colour being deep red. Its plasticity is good, the character of the burned body excellent, and as far as the tests have gone, these show it to be one of the best brick materials of the region.

The deposit at this point is scarcely extensive enough, as the construction of the railway line across it renders the greater part of the bed unworkable.

Although there are several thick beds of red and grey shale in the Sillery formation, no others were observed which had weathered to the plastic condition of the one mentioned. There is a considerable area of red soil in the fields, between St. Nicholas and St. Appolonaire on the Intercolonial railway, west of Levis, which is probably the weathered portion of red shale beds of the Sillery formation. This area might be worth investigation by those interested in the production of a high grade red building brick.

Clayworking Industry.

Common bricks are made in at least sixty different localities in the Province of Quebec, from the surface clays.

The silty or lean clays, which work easily, and dry quickly, are the ones used by the brickmakers. The fat or highly plastic and stiff clays are avoided. The clays at St. Johns, Nicolet, and L'Epiphanie, etc., which are hard to work and difficult to dry without cracking, are of the latter type, and are not used.

The surface clay plants make nothing but soft mud brick, which are generally dried on an open floor, and burned in clamp kilns. From 500,000 to 3,000,000 bricks are produced annually by individual yards. In the outlying districts the industry is spasmodic; a plant will shut down for a year or two and then perhaps start up again, according to the local demand.

The plants within reasonable distance of Montreal have been producing steadily in recent years.

The bricks generally produced are not good, and too many light or under-burned ones are shipped. The bricks are also badly made and frequently deformed, the result of using too soft a mud.

The surface clay is used at Lakeside, 13 miles west of Montreal, for the purpose of making terra-cotta lumber, or porous fireproofing as it is sometimes called.

No field drain tiles are at present produced in the Province, although much of the land under cultivation would be greatly improved in production by its use. Clays at Hull, Ormstown, Montreal, and St. Jean Deschaillons, would probably be found suitable for the manufacture of this class of clay products.

One of the minor uses of the surface clays is in the manufacture of Portland cement. They are used at two localities in the Province of Quebec for this purpose.

The rapid growth of the city of Montreal during the last two years, and the replacing of older buildings in the central portion of the city by more modern structures, has brought about a demand for a local brick in large quantities, of better quality than the common brick, hitherto made from surface clays. To meet this demand three large plants have been erected in recent years on the south side of the St. Lawrence river, situated at Laprairie and Delson junction, 14 and 18 miles from Montreal.

The materials used for the manufacture of the bricks are shales of the Utica-Lorraine formation, to which is added some of the very plastic surface clay. These plants are equipped with the most improved types of clayworking machinery, driven by electric power. The principal product is a wire-cut red building brick, but a considerable quantity of dry-pressed bricks are manufactured. The burning is done in both downdraft and continuous kilns, fired with coal or coke. The output for a working day for the combined plants is estimated at 750,000. There is quite a demand for these bricks in the larger towns, but the greater part of the production is sold in Montreal.

The Citadel Brick and Paving Block Company erected a plant during the season of 1912, near the city of Quebec. The material used is the Lorraine shale from the escarpment which extends from Beauport to Ste. Anne de Beaupre, the works being located near Montmorency falls. The first bricks produced by this company were burned during the month of January, 1912. The samples sent out were wire-cut brick of excellent quality. A very desirable tapestry brick, for facing purposes, could be produced by this company from the shales they are using.

It is the intention of this company to produce paving blocks from their shales in the near future. These shales will probably make pavers, by careful burning, but the margin between the vitrification and softening point is rather small.

All the surface clays, and most of the shales in the region burn to a red colour,

but there are some localities in which the Utica-Lorraine shales are buff burning. The shales which are so far known to burn to a buff colour are found at St. Augustin, Beauport, and Montmorency, and at a few other localities in the eastern portion of the area.

The production of hard burned fireproofing, or hollow building blocks and flue linings has not been undertaken yet in the Province, although there is a great demand for them, which is now supplied from other sources.

A mixture of two parts of finely ground Utica-Lorraine shale to one of plastic surface clay, would probably give a good hollow-block, which could be manufactured in the vicinity of Montreal. The Medina shale found at St. Gregoire and Becancour would probably produce a better hollow block, but the locality is not so convenient to a market for them.

The shales now being used near Montmorency falls are probably plastic enough when finely ground to be used alone in the manufacture of fireproofing.

The manufacture of sewer-pipe has been carried on for some years by the Standard Clay Products Company at St. Johns. The body used for this purpose is composed of a mixture of surface clay—mined in the vicinity of the works—and fireclay, brought by water carriage from New Jersey. A certain amount of waste pipe is ground, and added to the clays. A strong, serviceable, salt glazed pipe is produced at these works, which is shipped to Montreal and Ottawa, and even as far west as Alberta.

No paving bricks are produced at present in the Province of Quebec. It is doubtful if any of the Utica-Lorraine shales will produce commercial vitrified wares of this class. When the laboratory tests now on hand are completed, it is possible that some vitrifying shales may be indicated. It may be possible to use the shales at Laprairie for paving bricks, by adding about 20 per cent of fireclay. The high price obtained for this product in Montreal would probably make it profitable to import the amount of fireclay required for the mixture.

The manufacture of sanitary porcelain is carried on by two plants in the town of St. Johns, the articles produced being limited to closet bowls and wash basins. The materials which enter into the composition of the bodies for this ware are flint, feldspar, kaolin, and ball clay, and are all imported from the United States or England.

The kaolin deposit at St. Remi d'Amherst was not worked during the season of 1912. A description of this deposit is given by Heinrich Ries in the Summary Report for 1911.

MARINE SHORE-LINES IN SOUTHEASTERN QUEBEC.

(*J. W. Goldthwait*)

Three weeks were spent, between June 13 and July 3, in a re-examination of the district between the Champlain valley and the city of Quebec. The primary object of this field work was to determine with greater certainty than had previously been possible the extent and height of submergence of this part of the St. Lawrence valley by the extinct 'Champlain' sea. Mr. Massy Baker, of McGill University, served as assistant.

The southern border of the submerged area, or 'marine plain' as it has commonly been called, was followed closely, on bicycle and on foot, from the Vermont State line to Cowansville and Sweetsburg, Que. Throughout this distance of about 15 miles the shore-line at what appears to be the upper marine limit is weak and topographically obscure, owing chiefly to the prevalence of a splintery slate formation at the surface, which furnished the waves with only the poorest sort of material for beach construction. On the more exposed points on the old shore there seems to have been very little cliff cutting, probably because the coast was already slowly emerging when the ice sheet withdrew from it. At one place, only, in a re-entrant a few miles northeast of Dunham, was a distinct gravel beach found at the upper border of the wave-washed area. The crest of this beach stands 509 feet above sea-level. A property owner in Dunham supplied information of two shell localities at approximately 400 feet; but no new shells were seen or collected there. Near Sweetsburg, remnants of an extensive delta of the Missisquoi river appear at an altitude of 505 feet, although the more extensive plain, here, is 70 feet lower, on account of the wide-spread dissection of the delta since its emergence.

From Sweetsburg northward to Shefford mountain this shore-line was very irregular; and the chance of discovering distinct beaches along it was thought to be so small that the available time was given up to an examination of the slopes of several low outlying hills, which were formerly islands a few miles off shore. One of these, just south of Granby, displays conspicuous beaches up to the height of 506 feet, with an obscurely washed zone reaching perhaps 10 feet higher. Others, between Granby and South Roxton station, afford similar evidences of submergence up to 540 and 552 feet respectively.

The irregular mainland shore of the Champlain sea appears to extend in a general northeasterly direction from South Roxton toward Kingsey, where there was a deep re-entrant, at the mouth of the St. Francis river, and a sheltering ridge near French village. Northeast of Warwick station distinct beaches occur at about 500 feet. The higher ground shows no sign of submergence.

At Arthabaskaville an examination of ground beyond that which was visited in 1910 led to the discovery, 2 miles northeast of the village, of good beaches reaching up to 552 feet. These can be traced about a mile along the hillside but gradually disappear in the district formerly visited, where conditions of slope and of slate structure at that altitude did not favour a good record.

At St. Julie the highest reliable beach deposit seems to be at 591 feet. Between here and the city of Quebec, where the submergence, as previously reported, appears to have reached 630 feet, no new data were secured.

This stretch of 150 miles along the shore of the late Pleistocene sea remains one of the most unsatisfactory fields in the lower St. Lawrence. Not only do the

waves seem to have found conditions very poor for shore-line development, but the relation of the retiring ice to the estuary is very uncertain, and apparently complex. All that can be said at present is that from the end of Lake Champlain northeastward to Quebec city the upper limit of submergence seems to rise very gradually, and not altogether steadily from 500 to over 600 feet.

At Montreal several days were occupied in locating the upper marine beach. Prof. F. D. Adams kindly pointed out the spot where Baron Gerard de Geer, in 1892, found what he regarded as the upper marine limit, at 625 feet. This is a bench on the northwest side of Mount Royal, behind the Protestant cemetery. There seems to be little difference between this bench and others at various altitudes on the mountain, which bear no visible relation to wave work, but have been developed by processes of weathering active on jointed structure. Since it appeared necessary to reject this 625-foot measurement of de Geer, therefore, an independent search was made and characteristic gravel beaches were found in two places at no great distance from de Geer's locality—one being just inside the Mount Royal cemetery and the other on flat ground just below the park ranger's house. Careful measurements from bench marks placed these two fragmentary beaches at 564 and 568 feet respectively. It was subsequently learned that the beach near the park ranger's house is Sir Wm. Dawson's highest marine shell locality, as stated in his 'Canadian Ice Age,' on pages 62 and 63.

A visit to Mount St. Hilaire led to the correction of the figure previously given for the upper marine limit on that ancient island. Above the 493-foot beach in Campbell park, which was reported in 1910, are equally good beaches of gravel, in favourable places, from 543 to 560; and other more obscure ridges of gravel to 570 feet. This part of the mountain is so thickly wooded that the beaches easily escape notice. The slopes above 570 feet, if ever submerged, would hardly afford distinct beach forms, as they are steeper and more limited in area.

If the 564- and 568-foot beaches at Montreal, the 560-foot beach at St. Hilaire, and the 552-foot beach at South Roxton are contemporaneous, lying on the same deformed marine water surface, the isobases in this district trend about 10 degrees north of east.

In order to connect these data with those obtained in 1910 at Covey hill near the New York State line, two visits were made to that district, one near the beginning and the other at the close of the season. On the first visit, to Sciota, N.Y., the highest of a group of conspicuous beaches, believed to be marine, was measured by spirit level, and found to have an altitude of 486 feet. This harmonizes fairly well with the 523-foot 'Gilbert Gulf' beach at Covey hill, the 509-foot beach near Dunham, and the beaches of Mount Royal, Mount St. Hilaire, and South Roxton already described; for, an isobase drawn from the Dunham locality, westward between Covey hill and Sciota, has a trend of 15 degrees north of east. The tilt rate of the Gilbert Gulf beach in this extreme northeast corner of New York state, however, appears to be nearly 3½ feet to the mile in a direction south 15 degrees east; while that from Dunham to the Montreal-St. Hilaire isobase in the direction south 10 degrees east, is but 2 feet to the mile. Possibly the warped geoid surface over Montreal is flatter than over northern New York because the Canadian district is nearer the centre of an up-domed area.

The last two days of field work were spent in conference with Professor H. F. Fairchild near Mooer's Junction, Sciota, and West Chazy, N.Y. The problem of correlating the data on the Canadian side with those collected last summer in eastern New York by Professor Fairchild has become unexpectedly difficult, as a result of the conclusion which he has been led to make, to the effect that the sea followed the retreating ice sheet northward, up the Hudson and across the Champlain valley, submerging the Covey Hill district to a point now 750 feet

above sea-level, or 225 feet above the plane of the Gilbert Gulf beach. No facts supporting this new theory have been found by the present writer on the Canadian side.

One day of the season was used in a trip to Rivière-du-Loup, 100 miles east of Quebec, where search for marine shells at a spot noticed a year ago from a passing train was richly rewarded. A ditch beside the track exposes an extensive bed of *Saxicava Arctica* and other Pleistocene shells of the Labradorean fauna. Its altitude is approximately 340 feet, or scarcely 35 feet below the highest marine beach at that locality. So productive a shell bed is rarely discovered so close to the upper marine limit.

JOGGINS CARBONIFEROUS SECTION, NOVA SCOTIA.

(*W. A. Bell*)

Introduction.

During the field season of 1912 the writer was engaged in continuing the work on the Carboniferous rocks of the Joggins section, Nova Scotia, commenced in 1911[1], and was furthermore instructed to resume the study of the Windsor strata and fauna about Windsor, Nova Scotia. The field work, begun July 4, was terminated September 26. The writer was so fortunate in the early part of the work as to be associated with Professor Schuchert of Yale University, to whom he is indebted for much help. He also wishes to express his appreciation of the co-operation of Dr. Hyde of Queen's University in the interpretation of the Windsor sections.

The Joggins Section.

The Joggins section comprises 40 miles of rocky bluffs facing north, along the shore of Chignecto bay, the northern lobe of the forked head of the Bay of Fundy. It is a remarkably complete pile of Carboniferous rocks, exposing unexpectedly to view in a region, flat and mantled with waste, an oblique section of an entire coal basin, known as the Cumberland coal basin.

This basin is in the form of a broad synclinal trough, having a present width of about 20 miles, trending in a general northeasterly direction in conformity with the regional Appalachian structure, and paralleling a youthful dissected highland to the south, the Cobequid hills. To the north the basin is limited by a well-defined anticline and a narrow belt of subsidiary folds, referred to later as the Minudie anticlinorium, but rocks mainly equivalent to the lower members of the Joggins series extend with general low altitudes beneath the lowland of New Brunswick.

From the Chignecto shore eastward, the syncline preserves its regularity of structure for 20 miles inland, where transverse folds and faults again bring up the lower rocks in a belt some 12 miles wide, which is partially occupied by the watershed between the Bay of Fundy and Northumberland strait. From here eastward to the strait the synclinal character of the trough is again manifest, but interrupted by secondary folds, until it sinks gently beneath the waters of St. Lawrence gulf. In the extreme southeast, however, it is no longer limited so completely by the Cobequid plateau, but passing around several outliers of the older rocks, merges into the Pictou coal basin.

PREVIOUS WORK.

In 1842 Lyell[2] made his first visit to this now famous section, and was impressed by the abundance of erect trees to be seen. Sir William Logan[3] in 1843 published a careful description and detailed measurement of the northern limb of the Joggins section as exposed from Mill creek at the base of the section to the

[1] See Summary Report, Geological Survey, for 1911, pp. 328–333.
[2] Lyell, Life of Sir Charles Lyell, vol. 2, 1881, p. 65.
[3] Logan, Geol. Surv., Can., Report of Progress for 1843.

uppermost beds at Shulie. In recognition of the seeming continuity in the sedimentation of his 14,570 feet of strata, he divided the section more or less arbitrarily into eight divisions, but each group was characterized on the whole by a dominance of certain characters. Fresh from his experiences in the British coal fields, he was the first to appreciate the significance of the numerous ancient soil beds and underclays so well exposed to view, in illustrating the formation of coal *in situ*. Dawson[1] in his second edition of his 'Acadian Geology' in 1868 presented an accurate and very readable account of the regional geology, with additional detailed observations on the sedimentary sequence, and mode of origin of the beds, and with illustrations and descriptions of the characteristic flora and fauna, To Fletcher and Ells is chiefly due former interpretations of the difficultly ascertained structure of the largely concealed inland portions of the basin. Ells's final report is contained in Part E of the Annual Report of the Geological Survey of Canada, Volume I, with an accompanying map of the greater part of the district concerned in the present report. Fletcher's map (Apple River sheet, Nos. 100 and 101), published by the Geological Survey, embraces the remainder of the area, while his various statements concerning the geology are contained in several annual reports. Of particular interest is his published measurement and description of the rocks on the southern limb of the syncline[2].

The writer, in the Summary Report for 1911, drew attention to the probable terrestrial and fluvial origin of the whole of the Pennsylvanian deposits of the section, which were found to be separated from the underlying Mississippian beds at the base of the series by an accordant unconformity, or disconformity, representing a period of uplift and erosion. The absence of Permian deposits within the section was also noted.

PHYSICAL FEATURES.

The main area underlain by Carboniferous rocks forms the Cumberland lowland as contrasted with the Cobequid upland to the south. The surface of the lowland is nearly plane or only gently rolling, with an elevation of little over 200 feet above the sea, but rising gently to the base of the Cobequids to elevations of over 300 feet, and then rapidly to the 800- to 1,000-foot elevations of the upland surface. The monotonous character of the lower plain is broken, however, by low rolling ridges developed on the harder more resistant sub-rock and by such isolated monadnocks as Springhill (610 feet), Claremont hill (565 feet), Windham hill (625 feet), and farther east the Salem hills (450 and 590 feet). But properly this Cumberland lowland is only a portion of a much more extensive Carboniferous lowland of eastern Nova Scotia and New Brunswick, whose surface is broadly marked by its truncation and disregard of underlying structure, thus constituting a part of a peneplained surface, referred by Daly[3] to an early Tertiary epoch.

The Cobequid upland is considered by Daly as a higher residual plateau surface representing a remnant of a once extensive and continuous uplifted older plain, whose several surviving remnants now form the Cobequid upland, the southern plateau of Nova Scotia, and the Caledonia and neighbouring plateaus of New Brunswick. Daly[4] has correlated this upland plain as a unit, with the Cretaceous peneplain of New England. The Cumberland lowland is according to this interpretation a portion of a local peneplain carved in Tertiary time on the softer rocks of an elevated and warped Cretaceous peneplain, while the Cobequid upland may be considered as a residual mass of the Unakian type.

[1] Dawson, Acadian Geology, 1868.
[2] Fletcher, N. S. Inst. Sc., Proc. and Trans., vol. 11, pp. 500–550.
[3] Daly, Bull. Mus. Comp. Zool., vol. 5, 1901.
[4] Daly, Bull. Mus. Comp. Zool., vol. 5, 1901.

At the last annual meeting of the Geological Society of America, in New Haven, Professor Barrell read a paper on the Piedmont terraces of the northern Appalachians. His argument was to the effect that the Piedmont plain of the Atlantic slope, as shown especially in Connecticut and Maryland, is a complex of subaerially-dissected marine terraces, and not a simple resultant of Jurassic, early Tertiary, and late Tertiary peneplanation. Late Tertiary time, in particular, was stated to have been a period of progressive elevation, resulting in successive terraces of Pliocene and Pleistocene ages.

In the light of this new hypothesis and the evidence brought to bear upon it, it would seem that the whole question of correlation of the Acadian land forms with those of the eastern states of America would have to be reconsidered.

Late Tertiary history has been expressed in the Cumberland basin, by oscillatory vertical movements of lesser amount, resulting in the dissection of narrow valleys whose mouths have been subsequently drowned and converted into tidal estuaries. Tidal deposition, resulting in the aggradation of wide, fertile flats of marsh along the upper reaches of the Bay of Fundy, has, therefore, been, aside from glacial action, the most recent and conspicuous process, and one whose activity still excites the wonder of all visitors to this interesting region.

GENERAL GEOLOGY.

General Statement.

The pre-Mississippian rocks of the Cumberland area are confined to the region of the Cobequid upland, and consist of folded and metamorphosed strata intruded by igneous masses, the whole being known as the Cobequid group. The Carboniferous rocks are, however, not exclusively confined to the Cumberland lowland, as basal conglomerates of this age rest unconformably on the flanks of the upland, and occasional outlying or inlying remnants occur as isolated patches within the area of the Cobequid group. The classification of these carboniferous rocks as presented in the following table is provisional only, and as the terms are new, the older classifications of Fletcher and Ells are included for comparison.

Table of Formations.

	Fletcher	Ells
Late Pennsylvanian. Shulie formation (Thickness 2,136 feet, Logan)	Permo-Carboniferous	Permo-Carboniferous
Uplift and renewed erosion.		
Middle Pennsylvanian Joggins formation (Thickness 6,886 feet, Logan)	Productive or Middle Coal Measures	Productive or Middle Coal Measures
Uplift and renewed erosion		
Early Pennsylvanian Boss Point formation (Thickness 4,583 feet, Logan)	Millstone Grit	Millstone Grit
Disconformity.		
Mississippian Windsor formation (Thickness 2,000+feet, roughly estimated)	Lower Carboniferous	Lower Carboniferous
Unconformity.		
Cobequid Complex group. Pre-Mississippian=Pre-Carboniferous Complex crystalline group of altered sediments and igneous rocks.	Silurian and Devonian, altered sediments, and Devonian intrusives.	Pre-Cambrian, Cambro-Silurian, and Silurian, altered sediments. Pre-Cambrian and Palæozoic intrusives

Summary Description of Formations.

Cobequid Group.—Not sufficiently detailed work has hitherto been done to state adequately the relations of the rocks of the complex Cobequid group. The Cobequid upland is underlain predominantly by igneous plutonic and volcanic masses. Portions of the originally intruded sedimentary roof are present now in the central area only as scattered remnants, but in the southern belt of the upland there is a considerable development of altered sediments. These sediments are chiefly dark and grey quartzites, black slates, red and green argillites, green micaceous and chloritic schists, and locally subordinate crystalline limestone[1].

At Wentworth station, on the northern border of the upland, small outcrops of fossiliferous slates carry Silurian fossils, and Dawson on lithological grounds assigned the remaining unfossiliferous quartzites and slates of the Cobequid group,

[1] Dawson, Acad. Geol. pp. 561–562; Honeyman, N. S. Inst. Sci., 1873, vol. III, p. 345; Ells, Geol. Surv., Can., Annual Report, 1885, pp. 60E, 62–63E.

to the Silurian, with the exception of a few plant-bearing rocks doubtfully referred to the Devonian, but which are seemingly of Pennsylvanian age. Fletcher[1] and Selwyn[2] have regarded the entire Cobequid series as altered Silurian and Devonian sediments cut by Devonian intrusives. Ells[3], on the contrary, considered these rocks as predominantly Pre-Cambrian in age, but with Cambro-Silurian sediments flanking the range on the south, and with an isolated outcrop of Silurian at Wentworth station.

In the sections seen by the writer the igneous rocks have a complex relation to one another, which is probably the resultant of several distinct epochs of intrusion. A green basic rock, commonly referred to as diorite, occurs in dykes and irregular masses intruded into certain of the sediments, as well as into a batholithic mass of red granite or into red volcanic phases of the latter. These two rocks, with various differentiations, appear to underlie the central and northern areas of the hills. Stoping phenomena of these trap intrusions into a red quartz-porphyry are very noticeable near Squally point, west of the termination of the Joggins section at Spicer cove. The contact is a remarkably zigzag one with re-entrant angles and with large angular blocks of the intruded porphyry jutting into the intrusives. Similar phenomena, though not so apparent, occur along the Intercolonial Railway cuttings north of Truro where angular masses of an intruded quartzite roof may be seen resting on the intrusive diorite.

Joggins Section: Preliminary Statement.—The Joggins section is divisible into five major divisions, no one of which is sharply delineated above or below, but each is the effect of peculiar conditions of sedimentation. These, briefly enumerated, are as follows, in ascending order, with Logan's and Fletcher's equivalents:—

(*a*) A lower marine limestone and red shale division of Mississippian age, correlated with the *Windsor formation.* Includes Logan's Division VIII.

(*b*) A conglomerate, grey sandstone, and shale division of Pennsylvanian age, of fresh-water origin, and containing plant remains and thin coal seams, comprising the *Boss Point formation.* Includes Logan's Divisions VII and VI.

(*c*) A barren red shale and conglomerate division, included in the succeeding *Joggins formation.* Includes Logan's Division V, and, it is believed, Spicer Cove conglomerate (New Glasgow conglomerate of Fletcher).

(*d*) A sandstone and shale division, likewise of terrestrial origin, with plant remains and productive coal seams, forming the typical *Joggins formation.* Includes Logan's Divisions IV, III, and II (in part), and Fletcher's Sections XII and XI.

(*e*) An upper conglomerate division of terrestrial origin, embracing the *Shulie formation.* Includes most of Logan's Divisions II and I, and Fletcher's Sections X to I.

In naming these distinct formations it seemed more advisable to replace altogether the older classification rather than to redefine its units within the Joggins area. The older terms have been used over the whole Maritime area for many years, but are so broadly indefinite that much doubt and confusion has arisen in their use. This is especially true when the terms are to be applied to thick series of continental deposits which make up so large a portion of the Carboniferous in the eastern Provinces. The limits and brief characters of the new formational units will, therefore, be briefly described.

Windsor Formation and Minudie Anticlinorium.—Upper beds of the Windsor formation occupy the central portions of the Minudie anticlinorium which, on the north, succeeds the Cumberland synclinal basin. At the Joggins section they are chiefly brick red shales, and underlie a belt of low country, about 2½

[1] Fletcher, Geol. Surv., Can., Annual Report, vol. 5, 1890–91, p. 6 P.
[2] Selwyn, Geol. Surv., Can., Annual Report, vol. 6, 1892, p. 5 A.
[3] Ells, Geol. Surv., Can., vol. 1, 1885, p. 55 E.

miles in width, extending in an easterly direction from Cumberland bay to the River Hebert. To the south of this belt lies the complete succession of non-marine Pennsylvanian beds exposed in the Joggins section.

The general low or marshy character of the area of the Windsor formation renders the interpretation here of the structure and stratigraphic sequence difficult. The axis of the main limiting anticline crosses on the River Hebert between Minudie wharf, where brick red shales dip northward, and the Barnsfield bluffs, 1,300 yards southward, where limestone carrying fossils typical of the upper beds of Windsor dips to the south. The strike of this limestone, N. 75° W. (magnetic), is practically the same as the strike of the beds at the base of Logan's section, and its continuation should carry the limestone immediately to the westward of Mill cove, and underneath the Chignecto channel to the shores of Cape Maringouin, New Brunswick. The Joggins area just west of Mill cove is low and no outcrops are visible, but the shore at this point is strewn with fragments of the fossiliferous Windsor limestone, absent elsewhere on the beach. In Maringouin, however, on the Shepody shore, the limestone outcrops in association with a thick bed of underlying gypsum. It would seem, then, that limestone strata of undoubted Windsor age lie at a horizon at least 1,000 feet below the base of Logan's Division VIII. Moreover, the association elsewhere of red shales and Windsor limestone with thick beds of gypsum, as at Maringouin and on Maccan river, is good evidence for believing that gypsum underlies a portion of this belt from Mill cove to Barnsfield. Certainly there is no gypsum outcropping within the Joggins section proper, as has been inferred by Logan and others.

In contrast with the regularly uniform dips of the southern limb of the anticline, the beds of the northern limb adjacent to the axis are markedly disturbed. For instance, below Minudie a narrow closed synclinal at the wharf is seemingly followed to the north by a closed anticlinal and this in turn by a distinct overturned synclinal fold, indicative of thrust from the south. As the strata are concealed at intervals by marsh, there is also a possibility of faulting adding to the obscure structure. Farther north there is an extensive area of marsh known as the Elysian Fields, but beyond at Black point more than 1,000 feet of Pennsylvanian beds are exposed. They are brick red in colour and include conglomerates, sandstones, and shale, outcropping on the shore as low reefs. Though heavily cross-bedded, they dip in general about 20° northeasterly.

Thickness of Windsor.—Nine hundred and sixty-six feet of brick-red argillaceous shales, forming the base of Logan's Division VIII, are actually exposed below the base of the Boss Point formation in the Joggins section. As an additional 1,000 feet or more of concealed shales has been estimated to overlie the top of the Windsor limestone at Minudie, the thickness of this barren red series is probably at least 2,000 feet. This thickness, however, is not uniformly held throughout adjacent areas, and the Boss Point rocks were presumably laid down on a topographic surface of some relief, a circumstance which has been mentioned by Young[1] in the Moncton, New Brunswick, area.

Thus, at Dorchester cape, N.B., beds of quite a different character from the above and probably 700 feet in thickness, may be seen interposed between red shales similar to those at Mill creek, and the unconformably overlying Boss Point formation. They consist in the upper portion of light red, laminated argillaceous shales, frequently stained a light green colour, and containing abundant concretions as well as thin beds of unfossiliferous limestone. These beds, with their high calcareous content, may represent either continental deposits or, what seems more probable, may be the result of chemical and physical deposition in a warm, shallow abnormal sea or marine delta. The lower strata are more arenaceous and

[1] Young, Geol. Surv., Can., Summary Report, 1911, p. 315.

conglomeratic, terminating in a basal bed of dark red conglomerate, quite distinct in appearance from the red conglomerates at the base of the Boss Point formation, as the pebbles are more angular and exhibit a greater variety. They are then underlain by a concealed interval of nearly a mile, followed by an exposure of 800 feet of brick red argillaceous shale, like that at the Joggins. Assuming uniformity of structure and dip (not a very safe assumption in this area), there would be at least 3000 feet of these lower shales.

This upper series of calcareous beds near Dorchester is peculiarly interesting as suggesting a source for the concretionary limestone conglomerates present as lenticular channels or beds in the overlying Boss Point rocks both here and at the Joggins section.

Post-Mississippian Erosion.—Post-Mississippian uplift and erosion before the deposition of the Pennsylvanian rocks is marked in certain areas of Nova Scotia and New Brunswick by erosional unconformities. Furthermore, wide-spread land conditions are indicated by the fact that no sediments corresponding to the American Tennesseian have been found in the Maritime Provinces. This holds true for the Joggins section, as assumed in the Summary Report for 1911, but here the unconformity is accordant and is hence distinguished by the term *disconformity*. This great break in the sequence has been established the present year, and the disconformity fixed, by comparing the contact at the Joggins section with those along the Maringouin shore. The line of separation has accordingly been placed, not at the base of the conglomerates of Logan's Division VII, but 692 feet below the top of Division VIII, or at the base of the lowest bed of grey sandstone described in his work of 1843. The overlying Boss Point rocks are characterized by grey sandstones bearing abundant drift plant debris, which are like those of the higher beds, i. e., of Pennsylvanian age, and by the occurrence of basal conglomerates and channels or lenticular beds of the peculiar limestone conglomerates referred to above. These latter, in addition to the nodules of unfossiliferous limestone, contain pebbles of red sandstone and red shale, all of which could have been derived from the underlying rocks of Windsor age, such as are still seen at Dorchester. The geological history represented by this depositional break must, of course, be largely of a theoretic character, until further regional data are obtained.

It seems probable to the writer that the Cobequid mountains were established as a region of uplift as early as the middle Palæozoic, and that it partook of the orogenic movements of late Silurian and post-Silurian times. It was in late Silurian and late Devonian times that crustal movements occurred widely in western New England and in the Maritime Provinces. The faunal and structural evidence, so far as known, seems to indicate the existence of the Cobequids as highlands or islands in a Mississippian sea. Following the retreat of this sea, the region was one of extensive erosion throughout all later Mississippian time. Pennsylvanian conditions were then established, seemingly in part as the result of differential warpings along Appalachian axes, as suggested by the highly disturbed conditions of the Windsor strata in the area south of the Cobequids when contrasted with their moderate deformation to the north of this ridge. Possibly the changes were in part climatic in origin, the effects of the introduction of a more pluvial period. In either event, the Pennsylvanian history is marked dominantly by the deposition of terrestrial deposits in the form of fluvial flood-plains and subaerial delta deposits, which were derived in part from the large continuous areas of upland to the south and west, and in part from the forelying Appalachian mountain chains.

Boss Point Formation.—The Boss Point formation has been described in detail in Logan's section of 1843 (Division VII and VI), while its general characters are well presented by Dawson in his 'Acadian Geology,' under the term Millstone Grit. In brief, the formation is made up of two quite distinct divisions, a lower predominantly red division and an upper prevailingly grey division. The lower

red division consists of varying proportions of brick red quartz conglomerates and red argillaceous sandstones and shales. The upper division is made up chiefly of greenish grey, yellow-weathering sandstone, interbedded with brick red argillaceous shales, and with subordinate grey shales as well as thin seams of coal or carbonaceous shales, and thin beds of bituminous fossiliferous limestone. The typical sharp quartz sandstone of the upper division occurs at Boss point, which name is accordingly chosen to designate the formation. In the Joggins section the conglomerates, aside from the limestone conglomerates already mentioned, are confined to the basal members, but in New Brunswick, they are much more prevalent.

Post-Boss Point Uplift and Erosion.—Overlying the Boss Point sandstones in the Joggins area, there are in the northern limb of the syncline, in the vicinity of Lower cove, 2,000 feet or more (Logan's Division V) of brick red sandstones and shales which have hitherto been considered as upper members of the Millstone Grit and which are overlain by strata of the Joggins formation. There are grounds for believing that the 2,000 feet or more of red sandstone and shale should be classed with the Joggins formation and that they are separated from the Boss Point beds by a disconformity representing a period of uplift and erosion that intervened between the time of deposition of the Boss Point (Millstone Grit) and Joggins (Coal Measures) formations. The grounds for this belief are as follows:—

In the southern limb of the syncline, the Boss Point beds do not appear to be present. There the rocks of the Joggins formation are underlain by over 800 feet of brick red, coarse conglomerate which contains large subangular or angular blocks of rocks of the underlying Cobequid group, upon which it rests unconformably. It is thought that this red, coarse conglomerate may represent the red shales and sandstones occurring in the northern limb of the syncline at Lower cove, below the Joggins beds. Small outliers of conglomerate similar to that underlying the Joggins beds in the southern limb of the syncline are present in the western area of the Cobequids, sometimes associated with small thicknesses of overlying coal-bearing rocks. Such an outlier occurs near Advocate, where considerable excitement was aroused this past summer by the discovery of small quantities of coal. The seam was not definitely established and the small amounts of coal were apparently taken from a fault gouge, but the underlying rocks overlie a patch of conglomerate which rests unconformably upon black slates of the Cobequid group. At Parrsboro, on the southern side of the Cobequids, a similar conglomerate lies unconformably upon intricately folded strata, which, by reason of their fauna of *Leaia leidyii*, Lea, *L. tricarinata*, Meek and Worthen, *Estheria dawsoni*, Jones, etc., are correctly regarded as of Pennsylvanian time and correlated with the Riversdale. The Riversdale was correlated by Dawson in 1873 with the Millstone Grit, and its flora, along with that of the Millstone Grit, was stated by David White in 1901 to be closely allied to the Pottsville formation at the base of the Pennsylvanian of the Appalachian trough. The beds overlying the conglomerate at Parrsboro comprise over 2,000 feet of sandstones and shales including thin coal seams, and beds of bituminous shale which carry *Anthracomyas*, apparently identical in species with those of the Joggins formation. Because of this marked similarity in physical and faunal characters these higher beds at Parrsboro are not only correlated with the Joggins formation, but seem as well to indicate a renewed uplift of the Cobequid area in post-Boss Point time.

But the Minudie anticlinorium has also the Boss Point beds involved in its folding, which is of such a character as would result from thrust from the south. That is, the beds in the southern limb are gently inclined, while those of the northern are steeply tilted and in places disturbed by secondary overturned folds. It is further postulated, therefore, that the Minudie anticlinorium was a consequent

of the renewed uplift of the Cobequids in post-Boss Point time, and of the formation of a distinct Cumberland geosynclinal basin, as an effect of northward thrust.

In summation, it should be noted that the evidence for such an unconformity between the Boss Point and Joggins formations is supported by, but does not rest upon the close correlation of the Riversdale deposits with those of the Boss Point. The following facts are of equal importance:—

(1.) The correlation on the basis of their physical characters and contained plants of the one hundred feet or so of beds at Spicer cove in the southernmost end of the Joggins syncline with beds of the Joggins formation.

(2.) The sharp angular unconformable contact between the Spicer Cove conglomerate at the base of the above plant-bearing beds, and the Cobequid group. Boulders and angular fragments of schists, slates, or igneous rocks of the Cobequid group make up the coarse material of the conglomerate, and the character of these fragments in the conglomerate varies within small areas in close accord with the nature of the underlying rock.

(3.) Presence of local outliers of the Spicer Cove conglomerate in the western end of the Cobequids.

(4.) Presence at Spencer island, Parrsboro, etc., along the south flank of the Cobequids, of plant-bearing beds with associated *Anthracomya* shales, presenting marked similarities to the Joggins formation and not to the Boss Point or Shulie formations.

(5.) The sharp angular contact of the above Parrsboro plant-beds upon the Parrsboro *Leaia* beds. The basal conglomerate is similar in texture to that of the Spicer Cove conglomerate and is wholly unlike any known Boss Point conglomerate.

(6.) Lastly, the corroborative palæontological evidence of the lower Pennsylvanian age of the Riversdale beds.

Joggins Formation.—The position, then, of the 2,000 feet of red beds at Lower cove in the Joggins section, though doubtful, suggests that they may be in part synchronous with the deposition of the red conglomerates of Spicer cove.

The succeeding beds of the Joggins formation differ from the preceding Boss Point formation in the greater development of shales which are largely grey in colour, and in the increased number and importance of coal seams. A monotonous sequence is quite noticeable of zones of regularly evenly-bedded shales, thin sandstones, underclays, and coal, in alternation with massive, uneven beds of cross-bedded sandstone that characteristically channel into the underlying shale zones. The rapid deposition of these heavier sandstone beds is well attested by the fact that they frequently contain the casts of erect trees, occasionally exceeding 15 feet in height, whose bases occur in the mudstone soils beneath. These soil beds are abundant everywhere throughout the formation, in many cases still preserving the trees in their erect position *in situ.* Commonly in association with the coals are thin, shell-limestones which carry abundant *Anthracomyas*, *Spirorbis*, and Leperditian ostracods, a fact which may indeed be advanced as an argument in favour of temporary estuarine invasions, as the fauna is neither a distinctively marine nor a fresh-water one.

The Joggins formation is considered as extending from the vicinity of Lower cove to Ragged Reef point in the northern limb of the synclinal, but is also thought to be represented, as mentioned above, in the southern limb by a thin coal-bearing series at Spicer cove and by the underlying Spicer Cove conglomerate.

This Spicer Cove conglomerate is of peculiar interest as it has been correlated by Fletcher with the New Glasgow conglomerate, occuring at New Glasgow in the Pictou coal field, concerning the age of which there has been considerable controversy. Such a correlation seems to the writer unsafe and he would tentatively

correlate the New Glasgow conglomerate, not with the Spicer Cove conglomerate, but with the younger Apple River conglomerate to be described below.

In the area traversed there is scattering evidence, such as at Advocate harbour, in the presence of outliers, to indicate that the Joggins formation extended over at least a portion of the region now occupied by the Cobequids. Just to what extent the Cobequids were subdued in this period is not known, for a renewed Pennsylvanian uplift, soon to be considered, initiated a new period of active erosion. But it is scarcely safe at present to correlate too closely the formation at Parrsboro which rests unconformably above the folded *Leaia* beds to the south of the Cobequids with the Joggins formation to the north. It is probable they were in some areas continuously, in others synchronously deposited on opposite sides of low Cobequid divides. So far as present evidence goes, there are no coal seams of any economic importance in the formations about Parrsboro to the south of the Cobequids. Following the post-Boss Point tectonic movements which intricately folded the Riversdale estuarine series against the southern flank of the Cobequids, this southern basin seems to have been shallowed instead of deepened by the succeeding uplifts, while the reverse process seems to have taken place in the Joggins basin until the close of Pennsylvanian time when the whole region was vertically uplifted.

Post-Joggins Uplift and Erosion.—The peculiarities of the succeeding Shulie formation are the striking features of strong current action. The beds are dominantly coarse grits or conglomerates, and the greater percentage of the pebble content may be readily traced by lithological comparisons to its source in a Cobequid upland. Furthermore, the size of the individual pebbles increases markedly towards the old land. The presence of an appreciable percentage of sandstone and shale pebbles of Pennsylvanian aspect is additional evidence in support of a renewed activity of erosion in the Cobequid area in upper Pennsylvanian time. But corroborative evidence is found in the structures of the beds themselves, not only in their unsorted and uneven characters, but also in the appearance of the bedding planes of the pebbly sandstones or conglomerates. These show a markedly uneven surface in the presence of ripples or crests and hollows, the distance from crest to crest frequently exceeding 10 feet, while the furrows may be several feet in depth.

As some beds of the Joggins formation have been stated to have passed over at least a portion of the Cobequids, it seems necessary to explain these phenomena by a renewed uplift and erosion of the Cobequid area in post-Joggins time. The continuity of the sedimentation in the central areas of the Cumberland basin seems not to have been disturbed, but an unconformity or disconformity, representing a great time interval, must exist in the borderland of the Cobequids at Spicer cove, as apparently only the basal members of the Joggins formation are there preserved.

Shulie Formation.—The main characters of the Shulie formation have already been stated. There is an alternation of heavy, pebbly sandstones and conglomerates with thin zones of dark brown or chocolate mudstones and thin sandstones. The mudstones show, practically throughout the whole vertical extent of the series, evidences of former sub-aerial conditions in the presence of small vertical root-like carbonaceous stains, with an occasional conifer (*? Dadoxylon*, Dawson) *in situ*, whilst raindrop impressions are occasionally seen. Tumultuous current action seems necessary to explain the decidedly uneven bedding surfaces of the sandstones and conglomerates and the prevalence of channeling and cross-bedding. Drift logs of conifers and coal stringers derived from heaped up drift material are common.

The age of these beds has been referred by Fletcher and Ells to the Permo-Carboniferous, but the evidence derived from a provisional study of the flora suggests upper Pennsylvanian time, as *Lepidodendra* and *Sigillaria* still hold a prominent position.

Source of Material of the Carboniferous Group.—This question, though of con-

siderable interest, will be treated only briefly here. The main beds of the Windsor appear to have been deposited in embayments of a shallow sea which invaded the land from the east. At first these embayments were in open connexion with the outer sea, but gradually they became shallower, forming gypsum-making pans, and succeeded by mud flats, subject alternately to sub-aerial drying and to periodic floods. Extensive land areas to the south and west supplied the material for the wide-spread muds of this formation. Following the withdrawal of the Windsor sea, there was a long time of land and denudation in the Cumberland area, followed presumably by differential warping movements which initiated a period of terrestrial fluvial or brackish water deposition in the existing valley and geosynclinal troughs.

As we have seen, the Boss Point sediments were derived in part from the erosion of the underlying Mississippian formation of red shale, limestone, and sandstone. However, the constitution of the Boss Point conglomerate as a whole, and its relative abundance of well-rounded pebbles of vein quartz, points to dominant derivation from the more distant highlands to the north, south, and west. Thus on approaching the Caledonian upland of New Brunswick, the Boss Point conglomerates are seen to increase in quantity and coarseness, though still preserving the prevailing type of pebbles. But the Cobequids at this time may also have been mantled with waste and have furnished an appreciable part of the supply.

Following upon the extensive post-Boss Point rejuvenation of the uplands, there would be abundant sources for the sediments of the Joggins formation. The excessive sedimentation in the Cumberland area was due to the establishment, as a result of these movements, of the Cumberland geosynclinal trough. Thus pebbles from the coarser beds of the Joggins formation lying adjacent to the present Cobequids can be directly traced to the old Cobequid highland. At the Joggins section the sediments of this formation are dominantly fine, but at Styles brook, 15 miles inland, heavy beds of conglomerate, over 1,000 feet in thickness, are said to occur underneath the coal seams. The pebble content of these Styles conglomerates is described chiefly as red syenite, quartzite, and porphyry, ranging in size up to 2 inches in diameter, and such pebbles have undoubtedly been derived from the Cobequid group.

Lastly, the second great Pennsylvanian uplift of post-Joggins time gave a further renewed impetus to erosion, and a large percentage of the material in the Shulie formation can be traced without difficulty to the Cobequid series. At Ragged Reef point at the contact of the Shulie with the Joggins, vein quartz pebbles still make up nearly 80 per cent of the larger pebbles, as compared with less than 10 per cent at Shulie. Towards the south and the highlands the leading place is gradually usurped by granitic, quartzite, sandstone, and schistose pebbles. Thus in the Fitzgibbon Brook conglomerate, granites make up 5 per cent of the pebbles, while in the Birch Cove conglomerate they compose 50 per cent. Furthermore, the pebbles east of Shulie are in general less than 2 inches in diameter, while in the Apple River conglomerate they may exceed 12 inches. The presence further of a considerable percentage of red and greenish grey sandstones of Pennsylvanian aspect has already been noted, and at Apple river several interesting fragments of coal were found amongst the other pebbles.

In conclusion, it may be stated (1) that a large proportion of the finer material of the 13,600 feet (Logan's measurement) of Pennsylvanian beds of the Joggins section was probably derived from pre-Carboniferous highlands to the southwest, west, and northwest; (2) that the excessive sedimentation in the Cumberland basin was due to the establishment of a geosyncline in early Pennsylvanian time and to proximity to a Cobequid highland to the south; (3) that this Cobequid area was subject to periodic rejuvenations resulting in renewed activities of erosion; (4) that the derivation of these terrestrial sediments from the south, west, and northwest has resulted in an interfingering of synchronous lens-like deposits.

Furthermore, the establishment of these successive Pennsylvanian periods of uplift with their consequent effects on the sedimentation, explains what had previously been a mystery, viz., how a Cobequid upland of so narrow a breadth even of Alpine height, could have furnished any important contribution to the thousands of feet of Carboniferous sediments.

GREENFIELD AND LIVERPOOL TOWN MAP-AREAS, NOVA SCOTIA.

(*E. R. Faribault.*)

Introduction.

The writer's field work in Nova Scotia, during the season of 1912, consisted in the completion of the geological mapping of the southern part of Queens county extending along the Atlantic coast from Port Medway to Western Head and Broad river, and inland to Indian Gardens and Molega. The area surveyed measures about 20 miles east and west and 24 miles north and south. It is drained by the lower parts of the Medway and Liverpool rivers. This work completes the surveys necessary to finish the Greenfield sheet No. 94 and the Liverpool-town sheet No. 93.

In the area surveyed are situated the gold districts of Fifteenmile brook and Mill Village, special detailed surveys of which have been made. A detailed examination was also made of the gold district of Oldham in Halifax, surveyed in 1891, and a plan of which was published in 1898 on the scale of 500 feet to one inch. A general description of the geology of that district is here appended. Two visits were also paid to the tungsten deposits exploited by the Scheelite Mines, Limited, Company at Scheelite near Moose River Gold Mines, Halifax county.

I was assisted in the field during the whole season by J. McG. Cruickshank and Ralph A. Tapley, both of whom efficiently performed all duties entrusted to them. C. E. K. Jones was also engaged for three months in the first part of the season. Field work was commenced on June 6 and continued until the end of November.

Physical Features.

A general description of the character and geology of the lower part of the basin of the Medway river given in last year's Summary Report applies equally well to that of the Liverpool river lying immediately west. The Liverpool river takes its rise in the granite area to the northward in Annapolis county, and its upper stretches drain a flat, undulating region covered with numerous lakes, one of which, Lake Rossignol, is the largest fresh-water lake in the Province. The lower part of the river, which traverses the district surveyed last summer, flows in a southeasterly direction for 16 miles almost in a straight line from First lake, at Indian Gardens, to Liverpool bay on the Atlantic coast. This part of the waterway consists of a succession of stillwaters and easy-flowing stretches separated by some twelve important waterfalls and rapids which give a total fall of 241 feet in the 16 miles between First lake and the head of tide at Milton. On account of the exceptional storage facilities in the headwater lakes, these falls afford the most important water-powers available of any river in the Province. While some falls have already been developed and are utilized for pulp and saw mills, and for the electrical lighting of Liverpool and Milton, there is still a large total fall in the river which has not yet been utilized.

The following data on the principal water-powers of the Liverpool river were collected in 1910 by A. V. White, hydrographer, for the Commission of Conservation.[1]

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[1] Water-powers of Canada, Report Commission of Conservation, 1911, pp. 217 and 227.

Site	A. Sq. miles	B. Feet	C. Horse-power	Remarks
Milton lower fall.........	558	7–10	560	Several small mills and Milton electric plant.
Milton upper fall.........	558	7–10	560	Saw mills.
Cowie fall...............	558	20–22	1,550	Pulp mill; 1,500 horse-power developed.
Rapid fall...............	540	33	2,250	Pulp mill; 3,000 horse-power developed.
Guzzle...................	534	20–22	1,400	Town of Liverpool electric plant; 750 horse-power installed.
Lower Great brook.......	496	7	435	Banks high on eastern side at foot of falls; fall in about 1,000 feet.
Third Stillwater fall......	496	5	310	Banks high on western side, not very high close to river on eastern side; fall in about 800 feet.
Cowpen fall.............	492	6	370	Banks low on west side some distance from river bank.
Big fall.................	488	42	2,570	Banks fairly high on east side, falling off on west side; fall in about 5,000 feet.
Hemlock river...........	475	10	600	Banks receding with drop of river on each side; fall in about 3,000 feet.
Spring Bridge river.......	475	25	150	Banks flat; fall in about 500 feet.
Lake fall (Indian Gardens)	453	73	4,200	Banks high near Gardens, but low and flat from Pollard river to foot of Lake fall; fall in about 14,750 feet.

A.—Approximate area of watershed in square miles.
B.—Approximate head in feet.
C.—Estimated low-water 24-hour horse-power, 8 months, theoretical.

The measurements of flow of Liverpool river, metered October 11, 1910, in canal below head gates leading to municipal pond are as follows:—

Width of river where metered...........................	44	feet.
Area of river section...................................	99·5	square feet.
Discharge per second....................................	127	cubic feet.
Effective drainage area above section.....................	534	square miles.
Discharge per second per square mile.....................	0·24	cubic feet.

NOTE: Only one gate said to have been open at the Gardens. Two gates usually open at this season of the year.

Extensive contour surveys of the water system of Liverpool river have been made during the two last years by W. G. Yorston, hydrographer, for a company which proposes to develop and possibly transmit the hydraulic power to Halifax, about 90 miles distant.

On both sides of the Liverpool river, the surface rises gradually to a plateau incised by shallow valleys of minor streams, draining numerous lakes, swamps, meadows, and peat-bogs. The height of land dividing the waters of the Medway and Liverpool, attains an elevation varying from 300 to 500 feet above sea-level, and is generally made up of thick deposits of glacial drift in the form of lateral moraines having a general southeasterly trend. The rocks are well exposed along the Atlantic coast and some good sections are found along parts of the Liverpool and Medway rivers and some of their tributaries. The zone of slate stretching eastward from Indian Gardens through Greenfield, Chelsea and Baker Settlement, has suffered much glacial erosion as evidenced by the bare polished and striated surfaces which form a prominent feature of that area. In other portions of the

district the solid rock is for the most part concealed by drift in which are strewn numerous large angular blocks of rock detached from the thick beds of quartzose-sandstone of the region, rendering the surface very rough and generally too rocky for agricultural purposes.

General Geology.

The district examined is underlain by the Goldbearing series, together with a few small intrusions of granite and diabase along the Atlantic border. This series occupies the whole southern half of the peninsula of the Province from Canso to Yarmouth, and consists of an immense thickness of sediments which has been divided lithologically into two divisions: a lower one consisting of thick beds of quartzite with intercalated layers of slate, called the Goldenville formation; and an upper one composed essentially of slates, called the Halifax formation. After being deposited conformably on a sea bottom, probably in late Pre-Cambrian time, these sediments were closely folded, mostly during the early Devonian, in long east and west anticlines, then intruded at the close of the Devonian, by many large batholiths of granite and some dykes of basic rocks, mostly diabase. In the neighbourhood of the granite the sediments are metamorphosed into gneisses and schists. The age of the series cannot be determined by palæontology, as it is practically barren of fossils. From lithological analogy, they have been regarded until recently as Lower Cambrian, but now they are believed to be late Pre-Cambrian in age. The gold deposits are in the form of quartz veins, chiefly interbedded, which are found aggregated in large numbers on the domes of the pitching anticlines. Gold was discovered in Nova Scotia about 50 years ago, and since that time the annual production has fluctuated between $200,000 and $628,000, and the total production has been about 1,000,000 ounces, valued at $19,000,000, and recovered from 2,125,000 tons of ore mined, giving an average yield of $8.40 per ton.

The greatest width of the area of the Goldbearing series in the district examined, measured at right angle to the folding, is 24 miles from Medway head to Molega gold mines. A transverse section between these two points gives seven major anticlines and seven synclines with a few minor folds, particularly along the apex of the anticlines. The axes of folding were all located and traced across the area surveyed.

The following list of the anticlines and synclines gives the order in which they occur between Medway head and Molega mines, together with a few notes on their location and structure, and the distribution of the Goldenville and Halifax formations.

1° Syncline: Can be observed only at low tide on the shore of Medway head; pitches east; in the Goldenville formation.

1° Anticline: Passes 0·2 mile north of the main street of Port Medway and runs westerly through Eagle bay to the sea; pitches east; in the Goldenville formation.

2° Syncline: Begins in the vicinity of Medway railway station and extends westerly through Frelick cove to Liverpool bay; pitches east; in the Goldenville formation.

2° Anticline: Originates with the preceding syncline in the vicinity of Medway station and runs in a westerly course to Liverpool bay, 0·4 mile south of Government wharf. Several subordinate folds are developed between this and the first anticline, all diverging towards the west and pitching east in the Goldenville formation. Along these two anticlines on the shores of Liverpool bay are exposed the lowest known strata of the Goldenville formation, giving to this formation a thickness of over 18,348 feet of strata, which is 2,348 feet greater than that previously recorded at Moose river, Halifax county. This thickness added to the 11,700 feet of slates of the Halifax formation as exposed in the eastern part of the field will give

a total known thickness of 30,048 feet for the Goldbearing series of the Atlantic coast. In this estimate are not included the 2,800 feet of slates of the Gaspereau formation described in last year's Summary Report as probably overlying conformably the Halifax formation.

3° Syncline: Crosses Medway river half way between Mill Village and Charleston where it pitches easterly in the Halifax formation which outcrops in a zone 1½ miles wide and spreads out towards the east through Danesville on both sides of the Bridgewater road. It crosses the Liverpool river at Milton half way between the lower and the upper bridge, where the fold pitches westerly and the Halifax formation has a width of a little over 1½ miles.

3° Anticline: Crosses Medway river at Riversdale and pitches east in the Goldenville formation which is overlaid, 4 miles to the east, by the Halifax slates. It crosses Liverpool river between Rapid and Guzzle falls where it pitches towards the west. Two miles west of Medway river the anticline forms a long narrow dome, on both limbs of which gold-bearing interbedded veins have been developed in what is called the Mill Village gold district.

4° Syncline: Crosses Medway river at the head of Poltz falls in a zone of slates which is here overlying the Goldenville formation for a width of 0·2 mile and widens out in both directions on the east and west pitch of the fold. It runs westerly across Liverpool river 0·25 mile below Minard brook, where the Halifax slates terminate by curving broadly around the axis of the fold immediately east of Lower Great brook, and extend westward in the Goldenville formation passing at the north end of Shalnoes lake. Between the two rivers and directly north of the Mill Village dome the zone of slates forms a long narrow trough along which were observed some deposits of bog iron ore leached out of the pyrites contained in the slates.

4° Anticline and 5° Syncline: The axes of these two folds originate at the head of Glodes falls on Medway river, from where they diverge and pitch towards the east; the anticline passing south of Second Salter lake, across Patrick lake and through Leipsigate gold district, where it forms a large broad dome; the syncline crosses Big Winford and Ankle-Jack lakes, where the Goldenville formation is overlaid by the Halifax slates, and it terminates at Waterloo, a short distance west of St. Matthews lake, by joining the fifth anticline on the north from the west.

5° Anticline: Crosses Medway river 0·2 mile above the mouth of Dean brook and extends eastward to Rocky lake, on the east side of which the Goldenville formation is overlaid by the Halifax slates which spread out on the eastern pitch of the fold in several small plications. Toward the west, it runs through the northeast cove of Tenmile lake and crosses Liverpool river a short distance north of Bonmature brook, beyond which it passes at about the northern extremity of Bonmature lake and some distance north of Trout pond on the head-waters of Broad river; but the want of outcrops to the west of Liverpool river renders its location doubtful in that vicinity.

6° Syncline: Crosses Medway river at the mouth of Fifteenmile brook, 0·5 mile north of Bangs Falls bridge, in the Halifax formation. Eastward, it passes 0·5 mile south of Buckfield school house and at the northern extremity of St. George lake, and crosses the Pleasant River road 1·25 mile north of Newcomb post-office. Westward, it crosses Annapolis road at Middlefield, 0·6 mile north of Webber's hotel, and Liverpool river at the southern end of the island in Big Falls, and runs through the middle part of Long lake. This fold pitches east for its whole length, and 3·25 miles west of Annapolis road the Halifax slates are underlaid by the Goldenville formation, the boundary curving broadly a short distance east of Upper Great brook. On this fold and the following anticline and syncline, the Halifax formation attains a great development; the zone of slate, measured along Annapolis road from Queens County poor-house to Seventeenmile brook, has a

width of 4·5 miles, and it extends westerly through Indian Gardens and spreads out easterly across Lahave river into a large area.

6° Anticline: Crosses Medway river at Greenfield bridge where it pitches east 16° in the Halifax slates, and runs in an easterly direction parallel with the preceding syncline, crossing Pleasant River road one mile south of Baker Settlement post-office; westerly, it crosses Annapolis road 0·3 mile south of the bridge on Fifteenmile brook. The fold pitches east throughout the area and at the crossing of Fifteenmile brook, half-way between Greenfield and Annapolis road, the Halifax slates are underlaid by the Goldenville formation which forms a narrow zone spreading out towards the west. Several small folds occur along the apex of this anticline, and at the base of the Halifax formation along the north limb of the farthest north of these folds, gold-bearing veins have been discovered crossing the Annapolis road a short distance north of Fifteenmile brook. An interesting section of the numerous small crumplings of the slates on this fold are well exposed at Greenfield along the river.

7° Syncline: Crosses the southern part of Ponhook lake, 1·3 mile above Greenfield bridge, and was traced eastward through Gilmour Corner in Lower Chelsea to Baker Settlement, and westward to Aurnburg road. This is the deepest synclinal fold of the region and along its axis are found the highest strata of the Halifax formation.

7° Anticline: Passes through Molega gold district where the strata of the Goldenville formation form a dome which has a pronounced pitch towards the east, and on the northeastern part of which are found the numerous gold-bearing interbedded veins that were once extensively worked in that district. A detailed plan of the gold district showing the geological structure of the veins and the extent of the workings has already been published. From Molega, the anticline extends easterly across the southern part of Molega lake to Keddy point, where the Goldenville formation is overlaid by the Halifax slates, the boundary line describing a broad curve around the axis of the fold and following in part the eastern shore of the lake. Towards the west, the fold crosses Ponhook lake, touching the northern end of Big Lamouna island and the southern extremity of Maplesue point, and thence runs across the northern part of Big Moose Horn lake.

Along the sea-coast, from Eagle head westward to and beyond Western head, the quartzites and slates are metamorphosed into crystalline gneisses and schists by small intrusions of granite and diabase. The gneisses consist chiefly of quartz and mica, are foliated and coarsely crystalline. The schists are mostly composed of mica with which are often developed crystals of hornblende, staurolite, andalusite, or garnet. Numerous hard siliceous bands are heavily charged with well developed stout crystals of feather amphibolite showing in relief on weathered surfaces. In some cases pyrite or sillimanite were observed, particularly at Eastern head. As a general rule every gradation from unaltered slates and quartzites to completely recrystallized coarse schists and gneisses is noticeable as the granite is approached. The alteration due to the diabase intrusions does not extend more than a few feet from the line of contact, and the altered zone is generally impregnated with magnetite often weathering to red hematite.

In the area surveyed, the granite intrusions are quite small and confined to the shores of Liverpool bay. Between Moose harbour and Scott point, a small mass of light pearl-grey muscovite granite extends from the shore to the road, and numerous dykes and reticulated veins of the same granite are found along the shore as far south as Western head. At Beach Meadows a dyke of light grey, muscovite and biotite granite, varying in width from a few feet up to 500 feet, extends east and west for 1¼ miles along the shore, following in parts the strike of the intruded sedimentary rocks. It is accompanied by a few smaller dykes of granite or peg-

matite, of a coarser texture, bearing such minerals as tourmaline, fluorite, and lepidolite.

A dyke of coarse diabase, 330 feet wide, outcrops conspicuously on the seashore at Black point. The large dyke of diabase traced previously along the coast for 25 miles, from West Ironbound island to Cowie's Tannery brook, was described in last year's Summary Report.

Economic Geology.

GOLD.

Gold-bearing veins are the only deposits of the area that are of considerable economic importance. Gold quartz has been mined quite extensively for many years at Molega, and to a limited extent at Mill Village and Fifteenmile brook. No actual mining was in progress at these mines last summer, except some exploratory work at Fifteenmile brook and Molega.

A detailed survey of the gold district of Molega was made in 1904, and a plan was published on the scale of 250 feet to 1 inch. The plan shows the geological structure of the anticlinal dome, as well as the extent of the workings on the interbedded veins which are aggregated on the northeastern part of the dome.

Mill Village Gold District.—This district is situated on the eastern border of the plateau, at a distance of 2 miles west of Medway river, between Mill Village and Charleston, and is reached by a good wagon road. The quartzites and slates of the Goldenville formation are concealed all over the district by a great thickness of drift, averaging 20 feet where it was proved by mining development. The want of outcrops precludes the possibility of locating exactly the position of the anticline and renders the determining of the structure of the dome even more difficult, but it is evident from the prospecting work done and the outcrops observed farther east and west, that the anticline forms a long narrow dome which is favourable to the development of gold-bearing veins. The axis of the anticline strikes about N. 55° E. (magnetic) and the limbs of the folds dip south 54°, and north probably at a higher angle.

Development work has been confined to two localities, 4200 feet apart, the Gold Eagle mine on the southeastern part of the dome, and the Goddard prospect on the northwestern part of it.

At the Gold Eagle mine, gold quartz drift was first discovered in 1899 by J. F. Jones. Since then very rich drift was found and two interbedded veins have been developed, the South lead and North lead. The South lead strikes N. 50° E. (magnetic) and dips south 54½°. The workings on this lead consist of a shaft 200 feet deep, at the bottom of which tunnels were driven 12 feet in both directions, and a cross-cut driven south for 50 feet through hard quartzite with two or three layers of slate and no quartz, and a second cross-cut driven north, 80 feet, with a horizontal bore-hole extending 250 feet farther, passing through quartzite and no slate nor quartz. At the 100 foot level, tunnels were driven west 250 feet and east 200 feet, above which the vein was stoped to the surface. About 200 feet east and west of the shaft, prospecting pits are sunk through 20 feet of drift to the vein. The lead has a uniform width of 8 inches and consists of white and bluish grey mottled quartz, with only little sulphides. The gold is coarse, generally in pockets; one pocket of about 150 pounds is said to have yielded 110 ounces of gold. The working belt is a soft micaceous quartzite between walls of hard quartzite.

The North lead is situated 575 feet north, directly opposite the South lead, strikes N. 54° E. and dips south 54°. It is opened by two prospecting shafts 160 feet apart, the east one, 70 feet deep, through 20 feet of surface drift, and the west one, 25 feet deep, through 18 feet of drift. The vein is from 7 to 8 inches in width

and composed of dark cloudy quartz with very little sulphides, the gold being confined to a thin layer of dark laminated quartz, $\frac{1}{8}$ to $\frac{1}{2}$ inch thick, frozen to the footwall, on which was observed a thin coating of silvery white tremolite crystallized into fibrous-radiating forms. At the west shaft a small angular vein of quartz entering the lead from the northwest, forms an enrichment which, however, did not continue in depth.

Two other leads, each 3 inches in width, have also been opened 55 and 150 feet north of the South lead, but not worked.

It is estimated that the anticline passes 630 feet north of the North lead, and as very rich float has been found to the north as well as to the south of that lead, the zone between the North lead and the anticline should be considered a very promising field for further exploratory work.

The Goddard prospect lies about 4200 feet S. 78° W. from the Gold Eagle mine, and approximately 700 feet north of the anticline. The first discovery of gold drift was made in 1891 by an Indian, Solomon Newell (Noel). Much prospecting was done during the following eight years by Geo. Goddard and W. H. Prest. The richest float in the district was found here, derived from a 16 inch vein which has not yet been discovered on account of the great thickness of drift containing large blocks of quartzite. Two veins are reported to have been discovered by Goddard; one, 120 feet north of the base line, is 12 inches in width, and the other, 60 feet farther north, is 10 inches, but they apparently carried no ore.

OTHER DEPOSITS.

The valuable tungsten-bearing mineral, scheelite, was discovered in a quartz vein at Molega in 1894 and also at Fifteenmile brook and Huey lake, Baker Settlement, in the last few years.

Bog iron ore was observed at several places along the narrow zone of slate extending along the fourth syncline trough, between the Medway and Liverpool rivers, particularly to the east of Lower Great brook; it was also found at a few points along the seventh syncline of slate in the Greenfield district.

A deposit of 'rock flour' or glacial quartz silt, was observed at the dam of the mill-pond on Meadow brook which runs through the town of Liverpool. The material is composed of finely crushed quartz, nearly free from impurities, and the particles are highly angular and unweathered. The physical qualities of this sand may render it particularly serviceable in the manufacture of wood filler, paints, scouring soaps, polishers, and sand paper.

OLDHAM GOLD DISTRICT, NOVA SCOTIA.

(*E. R. Faribault*)

Location.

Oldham gold district is situated in the northern part of Halifax county, about 25 miles north of the city of Halifax, and 2 miles southeast of Enfield, a small station on the Intercolonial railway. The district lies near the summit of the watershed that separates the streams flowing south through Porters lakes, into the Atlantic, from those whose waters reach the Bay of Fundy by the Shubenacadie river. The altitude of the centre of the district is 317 feet.

Geology.

The quartzites and slates constituting the Goldenville formation of the Gold-bearing series (Pre-Cambrian) are here exposed in a subordinate anticline 9 miles long lying on the south limb of the Shubenacadie-Grand Lake anticline. The distance between the two anticlines is a little over 2 miles and the intervening syncline lies half a mile north of the Oldham anticline.

The fold which follows a ridge running east and west, is transversely symmetrical, the strata dip on both limbs at angles varying from 50° to 75°, and the axial plane is nearly vertical. The fold pitches to the east at angles increasing to 45°, but 2 miles east of the centre of the district, flattens out and disappears by meeting the syncline on the north; it pitches to the west at an angle great enough to completely conceal the Goldenville formation by the Halifax slate formation at a distance of 5 miles west, and finally also dies out by joining the syncline 2 miles farther at Wellington station.

The anticlinal fold thus forms a long and narrow, elliptical dome pitching to the east and west. In the western part of the dome the strata on both limbs run nearly parallel with the axis of the anticline, but finally converge and curve sharply within 10 feet over the apex; towards the east the fold becomes gradually broader and the strata form nearly concentric curves.

The horizon of the quartzites and slates of the Goldenville formation exposed on the dome is estimated to be 4,560 feet below the base of the Halifax slate formation, and as the thickness of the latter formation is 11,700 feet, a total thickness of over 16,260 feet of strata has been eroded on the dome.

The dome has suffered much faulting especially in the eastern part. An important fault follows the axis of the anticline from the centre of the dome eastward, and attempts to trace veins around the apex of the dome past the fault have met with poor success. Radiating from the dome towards the southeast is a series of important right-hand faults, two of which have horizontal displacement of 112 and 124 feet respectively. On the north limb are a few small breaks. A few flat faults having the nature of thrusts have also been met in underground workings. The faults do not continue for great distance on the strike nor in depth, and are later than the formation of the veins; but the Baker vein in the eastern part of the district occupies a fault plane cutting the anticline at right angles, which is of earlier origin and probably greater extent in depth than the other faults.

Character of the Gold Deposits.

With the exception of the Baker vein which has proved highly auriferous, all the veins worked in the district are of the interbedded type and are called leads. They follow fractures or slips along stratification planes and occur chiefly in beds of slate interstratified between beds of quartzite. The outcrops of the veins form almost complete concentric ellipses curving sharply at the western end and broadly at the eastern end of the dome. Over 25 interbedded veins have been worked and traced more or less continuously on both the north and south limbs of the dome. The vein-bearing zone is thus confined to the dome, on which it extends 8,100 feet east and west along the anticlinal fold and 1,600 feet across it.

The most productive part of the district is the eastern end of the dome, where the pitch of the anticline increases rapidly from 0° to 45°, causing there the maximum amount of fracturing across and along the stratification plane which produced rolls, corrugations, and angulars favourable to ore deposition.

Amongst the most important interbedded veins may be mentioned the Dunbrack, Sterling, Boston-Oldham, North Wallace, South Wallace, and Donaldson. A great number of others have been worked and many of them with profit.

The most important ore-shoots follow the rolls, which are quite prominent in the veins in the southeastern part of the district and pitch to the east at approximately the same angle as that of the pitch of the anticline. The two most persistent and richest ore-shoots worked on interbedded veins in the Province, were found on the Sterling Barrel lead and the Dunbrack lead in the southeastern part of this district.

On the Sterling Barrel lead, a rich ore-shoot has been worked continuously for a length of 1,610 feet by an inclined shaft following the pitch of the anticline on a dip increasing from 30° at the surface, to 43° at a vertical depth of about 900 feet. In 1909 the average yield of gold per ton was 2·88 ounces. The ore-shoot occurs immediately south of the anticlinal-fault, where the strata form a pronounced bulge or undulation of small horizontal width, but of great extent in depth on the apex of the anticline. The structure and character of the shoot was very regular from the surface to the bottom of the workings, its horizontal breadth varying from 100 to 150 feet. The vein is much corrugated, lies on the lower side of a bed of black slate, and is often 'frozen' to the quartzite foot-wall in which the corrugations sink and form furrows. Corrugations of the same character are well exposed 400 feet farther east on the foot-wall of a shaft lately sunk on the Rusty lead, which dips 31° east and is supposed to be the continuation of the Sterling Barrel lead on the north side of the anticlinal fault.

The Hardman mine on the Dunbrack lead is situated on the southeastern part of the dome where the strata begin to curve in a northeasterly direction towards the anticline and to dip at lower angles, with a development of corrugations in the veins. The Dunbrack lead lies on the foot-wall side of a bed of slate interstratified with quartzite dipping southeast 43°. Apart from the rolls, the thickness of the vein varies from a fraction of an inch to 8 inches, and may average 4 inches. The vein is corrugated and the corrugations pitch east 38° like those directly north on the foot-wall of the Schaffer Barrel lead. Two well-defined and parallel ore-shoots or rolls have been worked in the lead, the Ned McDonnell shoot and the Hardman shoot, pitching east at a lower angle than that of the corrugations. The upper one, the Ned McDonnell shoot, does not quite reach the surface but was worked for a length of about 850 feet on the pitch to the first fault of 112 feet, beyond which it has not yet been discovered. The ore-shoot measured in vertical section is 8 inches in thickness and 9 feet in breadth, having been thickened and enriched by small angulars entering from the foot-wall side.

The Hardman ore-shoot, which probably has produced the richest ore mined in the Province, lies about 140 feet below the Ned McDonnell roll and runs about parallel with it. It does not reach the surface, but lies at a depth of about 175 feet and a little east of the western end of the Ned McDonnell roll, where it originates like the latter in a small roll increasing in size and value as it pitches eastward 5° to 40°. It has been worked continuously on the pitch for about 1,200 feet across the first fault and as far east as the Whitehead fault beyond which it probably extends farther but has not yet been discovered. On the first fault the roll has an upthrow of about 130 feet and a horizontal displacement to the south of 112 feet. The thickness of the vein above and below the roll averages 4 inches, whereas it increases in the roll and varies from 8 to 22 inches, and may average 17 inches. In the roll the quartz and enclosing slate have a decided rolly structure, and vertical sections of the roll have the form of an elongated ellipse, the length or height of which varies from 8 to 18 feet. Small angulars of quartz, sometimes associated with siderite and seldom over an inch in width, branch off from the roll into the quartzite foot and hanging walls. Angulars entering the roll from the hanging wall had little or no effect on the richness of the ore, but those from the foot-wall side were decided feeders or enlargers of the quartz above them. It is important to note that the vein dips steeper below the roll than above it, producing a decided flexure of the strata which may account for the formation of the roll and the angulars by the slipping upward of one bed upon another during the folding process. Outside of the roll the ore had a general assay-value of 3 to 15 pennyweights (or $3 to $15) per ton in free gold, whereas the ore of the Hardman roll itself never yielded less than one ounce per ton; most of it gave 9 to 30 ounces, and sometimes as much as 80 ounces ($1,600) per ton for lots of 8 to 10 tons. The high grade ore was associated with galena and zincblende, the poorer quartz carrying from 1½ to 2 per cent of arsenopyrite, pyrite, and pyrrhotite, all of these minerals being found also in the rich ore but subordinate in amount to the galena and blende.

In the northeastern part of the dome a number of veins such as the Boston-Oldham and Frankfort, proved rich on their curve towards the apex of the anticline. Some veins have been worked extensively on the strike but to shallow depth.

North of the centre of the dome, several leads were enriched and thickened at the intersection of angulars entering obliquely from the southwest or foot-wall side and leaving on the northeast. The enriched and thickened part of a lead comprised between the line of entrance of an angular and that of leaving, is generally less than 20 feet in length and 100 feet in depth, forming a small ore-shoot called gold-streak or pay-streak. Several very rich gold-streaks have thus been formed on the Blue, Hall, and other leads where intersected by the Britannia angular, the ore yielding from 1 to 100 ounces of gold per ton.

In the northwestern and southwestern part of the dome a few leads have also been enriched at the intersection of angulars coming in on the foot-wall side from the southwest and northeast respectively. In the Blackie vein the gold was concentrated in arsenopyrite pockets, some of which carried as much as 5 to 7 ounces of precious metal, and outside of these the vein had little or no value.

In 1892, J. E. Hardman, manager for the Napier company, sank a vertical shaft 113 feet deep on the anticline on Area 102, cutting at the apex seven superimposed saddle-veins that do not outcrop at the surface. At the depth of 100 feet both legs of the saddles were intersected by cross-cuts driven 100 feet each way, showing the continuance of the saddle-veins to that depth and their conformity to the structure of the fold. It is said that two of the veins intersected were sufficiently auriferous to justify further development. This and similar developments in other districts point to the existence of a pay-zone extending

to a considerable depth in which a succession of auriferous, interbedded, quartz veins of similar character and extent lie superimposed one above the other.

At a short distance west of Hardman's vertical shaft, the Harrison, South Ohio, and some other adjacent veins are thickened several times their usual size on the apex of the anticline where they curve sharply within 10 feet and form ore-shoots pitching west about 20°.

In the Hay lead, lying outside of the district, 1,800 feet north of the anticline, an isolated pocket carrying 60 ounces of gold was found at the intersection of an angular with the main lead.

A pocket of 100 pounds of reddish scheelite was found at the depth of 40 feet in a large roll of quartz in the Schaffer Barrel lead on the eastern pitch of the anticline, where good examples of barrel-quartz structure can be observed at the surface. Occurrences of the same mineral are also reported from the South Wallace, Dunbrack, and a few other veins. Until recently the mineral was not identified by the miners who called it pinkeye, and as gold is not found associated with it they shunned its presence.

Production.

Gold was first discovered in this district in 1861. Active mining operations commenced the following year and have continued steadily to the present time. The official reports show that the yearly production of gold fluctuated between 282 ounces in 1897 and 3,171 ounces (for 9 months) in 1893, and the average yield per ton varied from 10 dwt. 21 gr., in 1881, to 3 oz. 5 dwt. 5 gr. in 1908.

The total gold production from 1862 to 1912 has been 67,343 ounces, valued at $1,279,520, extracted from 58,735 tons of ore. The average yield per ton is, therefore, 1 oz. 2 dwt. 22 gr. Local miners claim that the official returns of the production of gold from certain mines have been underestimated.

CLAYS IN LUNENBURG COUNTY, NOVA SCOTIA.

(*E. R. Faribault.*)

Four samples of clay collected last summer in Lunenburg county and transferred to J. Keele for examination, were submitted to a series of physical tests with the following results:—

A.—From Wallaback Lake Creek, Above Gold River, N. S. Lab. No. 21.—Small sample of light grey, soft material, probably diatomaceous earth, apparently taken from surface of deposit, and contains some mud. The deposit is badly sampled. This material is not plastic, so that it is difficult to mould into shape. Burned to cone 06 (1020° C.) it has a pink colour, very light porous body, and total shrinkage of 9 per cent. It is of no use in this condition for any structural ware, as the material is soft and friable. The purer diatomaceous earths are fairly refractory, and will stand as much fire as a fireclay without softening.

B.—From Chas. Keddy's Farm, New Ross, Lunenburg Co., N. S. Lab. No. 25.—Small sample of reddish clay, evidently the typical Pleistocene clay of Nova Scotia. Forms a smooth plastic body with 20 per cent of water, and has a shrinkage of 5 per cent when air dried. It burns to a good, hard, red body at cone 010 (950° C.) with low fire shrinkage. At cone 06 the colour is deeper and better; the fire shrinkage is 3 per cent, the absorption 12 per cent, and the bricklet almost steel hard. It vitrifies at about 1100° C. The material is useful for common red brick, drain tile, or porous terra-cotta lumber. The Pleistocene stratified clays of Nova Scotia, of which this is a type, are about the best brick clays in Canada.

C.—Small Sample of Silty Clay from Mahone Bay, N. S., Marked Elza Ernst, Shaft 50 *Feet.*—This material is of little or no value, the colour of the burned product being poor and the body porous, at the ordinary temperature of burning common brick.

Lab. No. 21*a.—This is a Mixture of No.* 21 *and No.* 25 *in Equal Parts.*—The mixture forms a mass of good plasticity, easily worked and dried. It has an air shrinkage of 4·5 per cent. It burns to a light red or salmon colour at cone 06, having a porous but strong body. The red clay No. 25 being partly fused, forms the bond for the mixture. The mixture will make a partition block, or fireproofing hollow blocks, standing any amount of fire, and will be sound proof and of low heat conductivity. If the cost of the diatomaceous earth is not too great, an industry might be created at this locality, from which the products could be shipped for long distances. It is worth investigation by the owners or people interested.

D.—From Shore of Lake Ramsay. Chas. Keddy's Farm, New Ross. Lab. No. 24.—Very dark grey or brownish clay, contains many small pebbles of quartz and feldspar and scales of mica. When ground to pass a 20-mesh sieve and tempered with water, it forms a very stiff sticky mass, hard to work. Its air shrinkage when dried is 10 per cent, which is excessive. The clay evidently contains a good deal of carbonaceous matter, as it is liable to swell and crack if burned too fast. It burns to a red colour, with further shrinkage, but gives a hard body. The poor working qualities, the high shrinkage, and the difficulty in burning, render this material useless in the clay working industry.

GEOLOGY OF THE NEIGHBOURHOOD OF NEW ROSS, LUNENBURG COUNTY, NOVA SCOTIA.

(*W. J. Wright.*)

Introduction.

Gold mining has long been the most important mining industry of southern Nova Scotia. As the industry developed, it was found that the economic deposits were confined to certain beds and structures of the sedimentary rocks known as the Goldbearing series, and in this region most of the detailed work of the Geological Survey has been confined to mapping the boundaries and structures of that important series. But the discovery of manganese and tin in the granites of New Ross, and the probability of further discoveries in other localities, drew attention to the great mass of intruded granitic material which covers such a large part of the interior of Nova Scotia.

At first the granites were considered to be of uniform age and the Summary Reports dealt chiefly with the detailed descriptions of the mineral deposits. But in the Summary Report for 1908, Dr. Young said that the country rock at the Reeve's tin mine was a fine-grained muscovite granite which appeared to be intruded into an older, biotite granite, and suggested the probability of similar occurrences in other parts of the Province.

The object of the season's work was to determine the extent of the fine-grained muscovite granite at New Ross, its economic importance, and occurrence in other parts of the Province. At New Ross the fine-grained granite was found to be an aplitic phase of a large batholith of muscovite granite which is intruded into the biotite granite and the Goldbearing series. The nature of the two granites, their relations to each other and to the Goldbearing series, are all well illustrated in this area. By the time the geological field work was completed in this district, it was too late to continue the work in other areas, consequently the present report deals only with the New Ross district.

The area examined in the neighbourhood of New Ross includes 216 square miles of country located about half-way between Chester Basin and Kentville. The settlements, lying in a narrow belt along the main wagon roads, embrace about one-third of the area. The remainder of the country is a wilderness of forest and barrens, lakes and swamps. The village of New Ross, in the south-western part of the sheet, is the distributing point for a rural population of about 1,300 people and thus is one of the largest centres of population in Lunenburg county. The village has a daily mail and telephone service, but is more or less isolated from the outside world by the lack of a good transportation line. Even the wagon roads are rough, and at times almost impassable.

Glaciation.

The distribution of the drift, and the glacial striæ show that the major movement of the ice-sheet was south, 20 degrees east. But north of the watershed there was also a local movement of the drift to the north. It is possible that during the final stages of the glacial period the continental divide was occupied by a local ice-cap which moved to the north as well as to the south. The retreat

of the ice left an abundance of boulder clay distributed over the country in irregular groups of low rounded hills, which have had a marked influence on the drainage and industries of the country.

Topography.

The district is part of the uplifted and dissected peneplain that forms the major topographic feature of Nova Scotia. Along the northern edge of the area, the restored surface of the plain has an elevation of about 600 feet. From here it has a general southerly slope of about 10 feet per mile. Outside of the main river valleys the surface has been well preserved, and at the present time it has a detailed relief of about 100 feet. But the main rivers have cut below the surface of the plain and flow in well marked valleys. This is especially true of the tributaries of the Avon. Where the south branch of that river crosses the north boundary of the area, it flows in a valley about 400 feet deep, forming the most rugged topography in the area.

While the major topographic features are pre-Glacial in origin, most of the details of the present surface are the direct result of glaciation. The relief of the pre-Glacial surface was so slight that the physiographic results of glacial erosion are not as marked as they are in regions of more rugged topography. The U-shaped valley of the Avon north of Vaughan, is the only example of its kind on the sheet. But, most marked effects resulted from glacial deposition. In the drift covered areas the surface conforms to the surface of the drift, the minor drainage has been entirely readjusted, and the main rivers are often ponded to form lakes or even turned entirely out of their pre-Glacial channels.

General Geology.

Table of Formations.

Superficial deposits: sands and gravels, boulder-clay, and clay	Recent.
Muscovite granite	Devonian?
Biotite granite	Devonian?
Goldbearing series	Pre-Cambrian?

SANDS AND GRAVELS.

The sands and gravels are found only in the valleys of the rivers. Most of them are being deposited at the present time, but along the Avon north of Vaughan, there are remnants of an old river terrace, about 20 feet above the present level of the river.

SWAMPS AND BOGS.

Many of the irregular depressions formed by the differential erosion and deposition of the ice-sheet, have been filled, and form swamps and bogs. The swamps are filled mainly by transported material, and support a dense vegetation of grasses and shrubs. When cleared they form valuable meadow lands. The peat bogs are filled by the decay of their own vegetation, chiefly mosses, and no doubt some of them contain economic deposits of peat.

BOULDER-CLAY.

Boulder-clay is made up of a complete mixture of rock fragments of all sizes from boulders 20 feet in diameter to the finest rock flour. It forms the chief agricultural lands in the country, and its distribution has largely determined the locations of the settlements.

CLAY.

A small deposit of impure white clay lies on the stream draining Camp lake, about one-fourth mile above its junction with the Gold river. Another deposit occurs at the head of Lake Ramsay. But when the locality was visited, the deposit was covered with water and its extent could not be determined. This deposit is said to underlie the boulder-clay.

BIOTITE GRANITE.

The biotite granite occupies almost the whole of the northwestern part of the area examined. It is a porphyritic rock with a medium grained groundmass. The phenocrysts are crystals of microcline, with inclusions of biotite. They are generally twinned according to the Carlsbad law, and vary in length up to 3 inches. The groundmass is made up chiefly of plagioclase, orthoclase, quartz, and biotite. It frequently has a bluish tint which is apparently due to the colour of the plagioclase.

Aplitic phases are common throughout the mass in the form of dykes and regular bosses up to 3 miles across. The rock is a fine-grained muscovite granite like that mentioned in the Summary Report on the Lahave valley in 1911. The dykes are in sharp contact with the walls, but in the larger areas there is a gradation from the aplite to the typical biotite granite.

Another variety of granitic rock is associated with the biotite granite and schist of the area northeast of Vaughan. The rock is made up of feldspar, quartz, and biotite. The crystal boundaries of the feldspars are not so sharply defined as those of the biotite granite, and biotite is much more abundant. Fragments of sedimentary rocks are scattered abundantly through the rock. Owing to the great amount of soil cover over this area, it was impossible to work out the field relations between this rock and the typical biotite granite. And the question arises as to whether it is a recrystallized sedimentary rock, or a basic phase of the biotite granite caused either by absorption of some of the sedimentary rocks, or by differentiation from the magma of the biotite granite.

MUSCOVITE GRANITE.

The muscovite granite covers almost the whole of the southeastern part of the area, and comes in again in the extreme northwest corner. In the main part of the batholith, it is a coarse-grained, porphyritic rock made up of orthoclase, plagioclase, quartz, biotite, and muscovite. Orthoclase is the predominant feldspar, and occurs as phenocrysts as well as in the groundmass. Plagioclase is scattered through the groundmass. Quartz is more abundant than in the biotite granite. Muscovite and biotite, are present in varying amounts.

In general the texture is fairly uniform, but there are areas where it varies greatly. This is especially true of a belt about one mile wide along the northern boundary of the southern area. Here we find all varieties of texture grading into each other, sometimes within a few inches.

The fine-grained muscovite granite of the Reeve's tin mine is an aplitic phase

of the muscovite granite. Rock of this type is liable to be found anywhere through the mass. Sometimes it occurs in distinct dykes, and sometimes it forms considerable areas grading each way into the typical granite. It is usually accompanied by a great amount of pegmatite. The pegmatite occurs in masses of all sizes from small 'nests' one inch in diameter, to large 'blow-outs' 50 feet long and 20 feet wide, and always grades into the aplite. Most of the prospects for tin and associated minerals are in pegmatites of this description.

While there are considerable areas of the aplite, it would be impracticable to attempt to map them on maps of the published scale. All that can be said is that they are most abundant in the belt mentioned in the preceding paragraph.

AGES OF THE GRANITES.

The ages of the two granites have not been determined. At present all that is known is that the muscovite granite is intruded into the biotite granite, and that the biotite granite is intruded into the Devonian rocks north of the district. Farther east in the Province, granite is overlain unconformably by the Carboniferous, and it is generally consided that the granites are of Devonian age. Judging from the mineral composition and the nature of the contact of the two granites, it is possible that they are closely related in origin and age, and that in other areas one may grade into the other.

GOLDBEARING SERIES.

The Goldbearing series of Nova Scotia has been divided into two conformable divisions: the Goldenville quartzites, known throughout the Province as 'whin,' and the overlying slates of the Halifax division. Microscopic study of 'whin' from the Lahave valley shows that the detrital material is chiefly quartz and feldspar, and the rock is, therefore, not a true quartzite. This is probably true of most of the division.

In the New Ross area, the Goldbearing series is confined chiefly to two lenticular belts lying between the two granites. The central belt, consisting mostly of 'whin,' extends from Camp lake to Leminster. The structure is well preserved and the belt takes in part of the south limb of an anticline. The crest of the anticline has been preserved for a short distance on Wallabach lake, and, at Leminster, the southern boundary swings south far enough to take in a small area of the black slate. The eastern belt, lying north of Vaughan, is made up of 'whin' and biotite schist. The latter is confined to the eastern side of the belt, and is possibly the metamorphic equivalent of slates of the Halifax division.

Economic Geology.

Many interesting minerals have been found in the New Ross locality, most of which are pneumatolitic in origin and connected with the pegmatites of the muscovite granite. Considerable prospecting has been done, and claims located for manganese, tin, tungsten, and molybdenite. But, as yet, manganese and tin are the only two which promise to be of economic value.

MANGANESE.

Manganese has been mined from two leads known respectively as the Old mine and the New mine. Other leads have been located, but as yet no work has been done on them.

The Old mine is located on a fissure zone in biotite granite about 9 miles north of New Ross. The lead strikes northeast and southwest, and has a steep dip to the north. The mine was opened in 1900 and worked for three years when it closed down on account of litigation. The following description and figures were obtained from one of the miners: A shaft was sunk on the lead for 115 feet, and at 100 feet, drifts were run to the east and west 10 and 20 feet respectively. About 100 tons of ore were shipped, and another 100 tons were stripped ready to mine when the mine closed down. The mine is much drier, and the walls are firmer than in the New mine. On the other hand the ore is not quite as high grade.

The New mine, located about 10 miles north of New Ross, was discovered in 1902. In 1910 the Nova Scotia Manganese Co., of Windsor, began developing the mine. Since then the company has erected an up-to-date mining plant, and is now engaged in building a graded road from the mine to Benjamin mills.

The mine plant consists of a concentrating building, a main power house with a return tubular boiler and a 50 horse-power engine, a combined shaft and storehouse, a small powerhouse containing a small engine to operate the hoist and a Cornish pump, a saw-mill to cut timber for the mine and firewood for the furnace, an office, and a cookhouse. The concentrating mill is 59 by 60 feet and four stories high. In addition to the concentrating machinery, it contains a storeroom and bunk-house.

The lead is a fissure vein striking north-east and southwest, and dipping to the north at angles of from 70 to 90 degrees. It varies in width both vertically and horizontally from 1 inch to 6 feet. The vein filling consists chiefly of various oxides and hydroxides of manganese and iron. The most common manganese mineral is pyrolusite, but manganite and psilomelane are both present. The relative amount of iron and manganese varies from pure iron in some parts to pure manganese in others. When the iron is present, it generally holds to one side or the other of the lead, and there is little trouble in separating it from the ore.

The country rock is biotite granite. The groundmass is a little finer grained than in the typical rock. Along the walls of the vein the atmospheric waters have changed the plagioclase to kaolin, and the biotite to a chocolate brown colour, while the microcline phenocrysts remain quite fresh. On exposure to the air the kaolin decomposes, and the result is a mass of rusty clayey material with an abundance of loose microcline crystals. In some instances, the plagioclase of the wall rock has been replaced by iron compounds and the result is a mass of iron ore with phenocrysts of microcline. There is generally enough of the altered rock along the vein to allow plenty of room for mining purposes; but on the other hand, the timbering of the mine has to be tight, and kept right to the working face.

The mine is developed by a 160-foot shaft on the dip of the lead. At the 150-foot level, drifts have been run about 160 feet each way on the lead.

The ore is sorted in the pit, loaded in skips, hoisted to the surface, and dumped on the washing floor, where it is hand-picked, washed, and put in the dry room. The dry ore is hoisted to the fourth story and fed into a Sturtevant jaw crusher. From here the ore passes downward and by the aid of a series of separators and a centrifugal roll, is separated into five sizes, four of which are merchantable. At present the fifth size is stored. But they are installing a Cristy Norris disintegrator to manufacture it into the air-settled grade.

TIN.

All of the prospects for tin are located in the muscovite granite, but there are only two that are worthy of mention here.

The Reeve's tin mine, located south of Lake Ramsay, is a 20 foot shaft on a pegmatitic zone in aplitic muscovite granite. The bulk of the pegmatite

is made up of feldspar and quartz. Associated with these are many pneumatolitic minerals of which muscovite, lepidolite, and fluorite are the most common. The cassiterite is said to have occurred as nuggets in the open spaces among the other minerals.

The pegmatite zone is 10 feet wide, and has been stripped for 20 feet. It was thought that this was the full length of the zone, but further development has shown that it may continue farther towards the east. The zone has no distinct wall, but grades into the aplitic country rock. Thus it is not a true pegmatite dyke, but an example on a large scale of the 'blow-outs' which are so common in this type of rock.

The other interesting prospect for tin is on the north bank of the outlet of Camp lake about one-half mile below the lake. The lead is a well-defined zone 2 to 4 feet wide, made up of intersecting quartz stringers and the altered country rock. The quartz stringers have a general trend parallel to the main lead and carry chalcopyrite, pyrite, cassiterite, fluorite, and associated minerals. The mineral bearing solutions of the quartz veins have altered the walls into a greenish silicified mass which grades into the fresh granite about 1 foot from the vein. Generally the quartz veins are so close together that the whole mass of the included country rock is altered and mineralized.

The lead has been stripped north from the river bank for 350 feet, and two shafts sunk 30 and 50 feet respectively, and so far the nature of the lead has not changed. Southward the vein has been off-set to the southwest, about 60 feet, by a fault located in the bed of the river. As yet no work has been done on this part of the lead.

At the present time negotiations are under way to obtain an option on the property in order to do some further developing.

THE STRATIGRAPHIC RELATIONS OF THE RIVERSDALE-UNION AND WINDSOR FORMATIONS OF NOVA SCOTIA.

(*Jesse E. Hyde.*)

Introduction.

During three months of the summer of 1912, the writer was engaged in the field study of the Windsor limestone of Nova Scotia and in the prosecution of this work considerable was seen of the Riversdale and Union formations or their equivalents. Although employed for a few days each at St. John, N. B., Windsor, Parrsboro, Joggins Mines, Truro, and Riversdale, N. S., most of the time was occupied in the vicinity of Sydney, Cape Breton island, in the detailed examination of an important section and the surrounding country. A large amount of palæontological material was collected, which is now being carefully examined for the preparation of a report on the faunas. For such measure of success as has been attained in the amassing of material, much credit is due to Mr. Frederick K. Morris who accompanied the writer as collector, during two months, and whose untiring patience won collections from beds which appeared well-nigh barren.

The Riversdale and Union formations, or, as they are frequently referred to, the Riversdale-Union, are widely distributed shale formations occupying large areas between the north shore of the basin of Minas and the Cobequids, around the head of Cobequid bay, and northward and eastward from Truro. A total thickness of 10,000 feet has been assigned to them by Fletcher. Fletcher considered them as Devonian in age, indicated them as such on the maps of the Geological Survey, and stoutly affirmed his position against all palæontological evidence until the end of his work. He maintained that these beds lie beneath the Windsor limestone which had been accepted without hesitation as early Mississippian or Sub-Carboniferous in age, and it is quite certain that it was, in part, his belief in this order of superposition which led him to maintain his belief in the Devonian age of the Riversdale-Union.

David White, Kiddston, Henry Woodward, Hind, and others, working independently on the scanty fauna and flora of these beds, simultaneously came to the unqualified conclusion that they are of early Pennsylvanian age. These results were published by Ami[1], who accepted them fully, but in his statement of the stratigraphic succession he continued to follow Fletcher and placed the Windsor limestone above the Riversdale-Union, thus implying for it a Pennsylvanian age[2]. Later he acknowledged this error, giving as his reasons: (1) that Fletcher's supposed Union at Arisaig, which is there overlain by Windsor, though of Devonian age, is not the Union formation, and (2) that at Parrsboro, the beds which overlie the Riversdale-Union and were mapped by Fletcher as Sub-Carboniferous, are Upper Carboniferous, as shown by contained faunas. As the last case is complicated by faulting and as the faunas referred to are apparently Windsor, as will be shown shortly, these statements do not yet satisfactorily establish our knowledge of the field relationship of the Riversdale-Union and Windsor formations. Some writers,[3] following his earlier statement, continue to place the Windsor

[1] Canadian Record Science, vol. 8, p. 154.
Nova Scotia Inst. Sci. Proc. and Trans., vol. 10, pt. 2, pp. 162–178.
[2] Abstract, Bull. Geol. Soc. Am., vol. 13, p. 533, 1903.
[3] Grabau and Shimer, North American Index Fossils, vol. II, p. 648, 1910.

in the Pennsylvanian. Others have adopted the Windsor as a Mississippian formation, and the Riversdale-Union as Pennsylvanian, without considering what may be their stratigraphic relations.[1] Fletcher's intimate knowledge of the stratigraphy of Nova Scotia was well recognized and his positive assertions that the Windsor lies above the Riversdale-Union have caused considerable uncertainty of opinion in the minds of others familiar with the region, which has not, however, found expression in print.

A few days' work during the last summer in the vicinity of Truro, N.S., have failed to establish what is the relation of the Windsor to the Riversdale-Union, in the type locality of the latter, a result not unexpected in view of the long time Fletcher worked in the region without establishing it.

Carboniferous Section at Sydney, Cape Breton Island.

The detailed study of the section exposed at Sydney, Cape Breton Island, has firmly established the fact that at that point beds carrying the typical Riversdale-Union fauna overlie the Windsor limestones, and are themselves overlain by the Millstone Grit. The Sydney section is the only one so far known in which rocks carrying the Riversdale-Union fauna, and, therefore, presumably, of approximately the same age, lie with their original stratigraphic relations to the underlying and overlying rocks undisturbed. The name, *Point Edward formation*, is proposed for these beds at Sydney, because they are not nearly as thick as the Riversdale and Union and it is not apparent whether they are the equivalent of one or the other or of a portion of one. Indeed, although the occurrence is regarded as an important one because of its showing the Riversdale-Union fauna in this position, it cannot be asserted that the fauna indicates exact contemporaneity with any part of the Riversdale-Union. The fauna is one which evidently lived under special conditions and may have had a considerably greater time range than is represented even in the 10,000 feet of the Riversdale-Union. But that it is a Pennsylvanian fauna there is no room to doubt.

The section at Sydney has been well known, since it was first described by Robb in 1876.[2] The results of last summer's work necessitate a considerable revision of the lower part of this section, as described by Robb and by Fletcher[3]. In the descriptions and in the mapping, everything from the Millstone Grit down to the 'Carboniferous conglomerate' series was described as belonging to the 'Limestone series,' meaning, thereby, the Sub-Carboniferous or Windsor limestone. Only a small percentage of this so-called 'Limestone series' is made up of limestones. It is also readily subdivided into three distinct formations; to the upper one is here given the name Point Edward formation, the middle one is approximately the equivalent of the Windsor limestones, and the lower part is of unknown age, but probably not a great deal older than the Windsor series. The revised section is as follows, the thicknesses, except for the Windsor series,being based on Robb's and Fletcher's measurements.

PENNSYLVANIAN SYSTEM.

Productive Coal Measures.—Sandstones and shales with a number of workable coal seams and several thinner ones. Plant remains are abundant in the series; upright tree trunks are not infrequent in the shales, and roots and rootlets in position are abundant. Naiadites and ostracods are abundant in the black

[1] Schuchert, Paleography of North America, Bull. Geol. Soc. America, vol. 20, pp. 551 and 556, 1910.

[2] Geol. Surv., Canada, Report Progress for 1874–75, pp. 172–174.

[3] Geol. Surv., Canada, Report of Progress for 1875–76, pp. 398–406.

	THICKNESS IN FEET.
shales associated with the coals and much the same fauna is also found sparingly in an occasional thin limestone.............	1,970
Millstone Grit.—A massive, yellowish, coarse, feldspathic sandstone, with numerous pebble beds in the middle and lower portions. Occasional thin beds of coal occur...........................	3,625
Point Edward Formation.—(Name new, formerly considered the top of the 'Limestone series'). Alternating sandstones and shales which are predominantly red or purplish in colour. The sandstones are characterized by cross-bedding produced by current work. Occasional limestones occur which, with the shales, are sometimes mud cracked. A fauna, consisting almost wholly of a few species of *Anthracomya* and ostracods with *Leaia*, occurs in the beds of grey shale. This fauna is also found, in part at least, in the Riversdale and Union formations near Truro. This formation is correlated in a general way with those formations. According to Robb, the thickness is about..	700
MISSISSIPPIAN SYSTEM.	
Windsor Series.—Marine limestones and grey or red shales with occasional sandstones. The thickness here assigned, 600 feet, is only about half as great as that given by Robb. The following members can be distinguished:—	
c. Sandy shales, predominatingly red with at least four marine limestones, poorly shown, thickness estimated about..	200
b. Reddish shales and sandstones with beds of limestone which carry a fauna almost wholly of ostracods; only a few small marine lamellibranchs and gastropods are present. Thickness, about....................................	188
a. Marine limestones with red shales and coarse sandstones. The limestones are marine but with a limited fauna. Thickness, about..	211
Age uncertain, probably Mississippian, formerly considered the lower part of the Sub-Carboniferous 'Limestone series.' Red and purple sandy shales, sandstones, and conglomerates all loosely coherent, with occasional thin beds of barren limestone. Pebbles up to several inches in diameter are present, but they are, on the whole, not as coarse as in the formation next below. This formation was included by Fletcher in his 'Sub-Carboniferous limestone series' because of the presence of an occasional limestone bed. These are not known to carry fossils. The thickness given by Robb, which is here adopted, is probably much too great...	2,633
'Carboniferous Conglomerate Series'.—This was so named by Fletcher, but its age is unknown. It consists of red and purplish conglomerates, differing mostly from the overlying beds in their greater coarseness. In degree of consolidation, distribution, amount of folding, etc., it belongs to the overlying series and is probably not far removed from it in age. It rests on highly metamorphosed Cambrian and Pre-Cambrian rocks and was evidently deposited in basins between hills of these old rocks, or on the slopes of such hills. Thickness, according to Fletcher..	2,525

Fauna of the Windsor Series, at Sydney.

This differs considerably from the fauna found in these limestones at Windsor, but several of the species are identical and there is no question as to the general equivalence of the beds. On the other hand, many species appear which have not been recorded from Windsor. These differences appear to be due in considerable measure to the variation of the fauna from point to point. The following notes are the result of a preliminary study and are subject to considerable revision and amplification. The lists so far prepared show a fauna of about 50 species, but considerably more work must be done on them before even a preliminary list can be submitted. The faunas of the three members of the Windsor series vary considerably. That of the uppermost member is a pure marine fauna with corals, *Productus*, *Camarotœchia*, *Spirifer*, *Spiriferina*, *Composita*, *'Dielasma sacculus'*, several species of marine lamellibranchs and gastropods. That of the middle member is also marine but evidently developed under restricted or special conditions. Several species of ostracods, two or three species of small aviculoid or alate lamellibranchs, a small gastropod and the Foraminiferal species (?) *Nodosinella priscilla*, Dawson, comprise the whole of the fauna, so far observed. The fauna of the lower member evidently existed under more nearly typical marine conditions than did that of the middle member, but no such diversified fauna has been observed as is found in the upper member. Whether this is due to biotic conditions or differences in age cannot as yet be stated. The lower member is marked by the numerous species of *Productus* and by the alate lamellibranchs. Rather striking, also, is the restriction of the faunules of the several beds of the member and the appearance of different species in these beds. This tendency, the limitation of and difference in the faunules in successive beds, is believed to be due to varying biotic conditions.

Several species are common to the lower and upper members of the Windsor, among them *Productus, cf. arseneaui*, *Productus lævicostus*, *Pugnax dawsonianus*, and *'Dielasma sacculus'*.

One species only has been found common to the Point Edward formation and the Windsor series, the ostracod *Beyrichiopsis granulata* var. which is so strikingly distinct as to be easily recognized. It occurs in several beds of the Windsor, ranging from the basal bed of the lower member, into the middle of the middle member.

Erosional Unconformity Between the Windsor Limestones and the Point Edward Formation.

The record of another geological event, heretofore undetected, is found near Sydney, N.S., on the east shore of Boularderie island opposite Boisdale station on the Intercolonial railway. Boularderie island is a broad syncline, with a general north-south axis. The southern part of the island consists of Millstone Grit with a narrow, interrupted coastal border of 'Sub-Carboniferous limestone series' (as mapped by Fletcher) on both the east and west shores. This belt has been seen by the writer only along about 8 miles of its length on the west side of St. Andrews channel, from opposite George River station to opposite Boisdale station. Here again, two distinct formations have been mapped by Fletcher under the name 'Sub-Carboniferous limestone series' (see map sheet No. 12).

The upper part of the Windsor limestone is well exposed, and between it and the base of the Millstone Grit occurs a series of sandstones and shales predominantly reddish or purplish in colour, with some coal. This series is best shown at George brook, opposite Boisdale, where its greatest thickness is about 150 feet. It is certainly less than this at other localities nearby, and in some cases

is perhaps wanting entirely. As there are red shale beds and sandstones in the Windsor series at the same locality, superficial observation may fail to distinguish the two as essentially different. However, the contact between the two series is a sharp one. It is very irregular and rises and falls across the Windsor limestones so that at one point, at least 56 feet of shales and limestones are present at the top of the Windsor series, which only 200 yards distant are wanting, owing to erosion prior to the deposition of the overlying shales. Where the erosion plane cuts limestones they have weathered and dissolved to a depth of 15 feet, prior to the accumulation of the overlying shales. This solution was so extensive that the uppermost 3 to 5 feet of the Windsor limestones may consist only of loose, irregularly rounded, corroded pieces of limestone, closely placed, but held together only by the red muds which have sifted into them from above. The limestone throughout this weathered zone is stained red and is infiltered with red muds from above, so much so that it has been locally prospected for iron ore.

Unfortunately, no faunal remains were found in the 150 feet of beds lying above the Windsor. These beds, although much thinner, occupy precisely the position of the Point Edward formation at Sydney, between the Windsor and the Millstone Grit, and it is the writer's opinion that they are identical with it. Lithologically they resemble very much the beds in the upper part of the Point Edward formation around Sydney harbour, in which also no fauna has been observed. Such a thinning of the Point Edward formation is found along George river a few miles west of Sydney. There the Windsor series dips steeply to the eastward, away from a high mass of Pre-Cambrian. Not over 200 feet above these limestones and with conformable dips, lies the Millstone Grit. The interval is very poorly shown, but the contact of the Millstone Grit on the shale which intervenes between it and the Windsor, is clearly shown, and this, with other occurrences, makes it highly improbable that the section has been shortened by faulting. This is on the western limb of the northwardly pitching syncline which forms the Sydney Mines coal field; the type localities from which the Point Edward formation is named and where it is much thicker are on the eastern limb of the same syncline and the outcrop belt of the formation is continuous from one locality to the other, around the southern end of this syncline.

So far as has been observed in the Sydney and Boularderie Island occurrences, the bedding of the Point Edward formation is parallel to that of the Windsor limestones. If there was even slight tipping of the latter before the Point Edward formation was deposited, the difference is so small as to have escaped detection.

Great Unconformity Separating the Riversdale-Union from the Overlying Rocks North of the Basin of Minas and Around Truro, N.S.

A highly important fact is brought out by the outcrops at Parrsboro on the north shore of the basin of Minas. Fletcher there mapped a series of very thick shales as 'Devonian' (see map No. 83) and considered them in a general way as equivalent to the Riversdale and Union formations. The correlation with the Riversdale and Union is undoubtedly correct. The same fauna with *Leaia* and *Anthracomya* is abundantly present.

Resting on the upturned edges of these beds is a series of sandstones and shales which is at the very least 1,000 feet thick and probably much thicker. At the base of this series is a coarse basal conglomerate from 15 to 30 feet thick, composed of cobbles up to 1 foot or more in diameter. The beds above this conglomerate are pebbly but gradually become less coarse and pass upward rather rapidly into sandstones and shales of which the formation is mainly composed. The plane of the base of this series rests on the upturned beds of the Riversdale-

Union at an angle of nearly 90° to them. This contact is excellently shown at two points, one on each side of Parrsboro inlet.

The beds which are the equivalent of the Riversdale-Union series have been forced into a nearly vertical attitude and closely folded. They have been badly cracked during the process and these cracks are filled with secondary calcite. The formation overlying the contact is not so closely folded although its beds stand at high angles, sometimes nearly vertical. There is little evidence of shattering and crushing such as is seen in the underlying beds. It is very evident that between the periods of accumulation of these series, there ensued an era of mountain folding of considerable intensity and an era of erosion of considerable duration, and that following the accumulation of the upper series, there was at least one more era of mountain folding. Furthermore, the whole must have been accomplished after early Pennsylvanian time.

Fletcher mapped the overlying series as the Carboniferous limestone or Windsor series. Whatever the overlying series may be, it is not of Windsor age, but is at least post-early-Pennsylvanian. It becomes now one of the problems of Nova Scotian geology to determine the age of this upper series, in order that the date of the first period of folding may be more nearly approximated. Should the formation prove a new one, the name *Parrsboro* may be applied to it and, until such time as it can be correlated with some formation now named, it is well to have a designation for it.

As noted below, the formation which Fletcher mapped as the 'Carboniferous conglomerate' in the region about Truro, is probably the base of the Parrsboro formation. It occupies precisely the same position, lying unconformably on the Riversdale-Union.

Ami[1] considers the Parrsboro formation as of 'Upper Carboniferous' age and refers to it as follows: 'It has been ascertained beyond a doubt that in one instance (at West bay near Partridge island and Parrsboro, in Cumberland county, Nova Scotia) the [supposedly] Carboniferous limestone [of Fletcher] proved, on examination of the organic remains entombed in them, to be of true and undoubted Upper Carboniferous age.' Concerning this statement it is to be noted that at the locality referred to there are perhaps 200 feet or more of fossiliferous limestones and shales which are faulted into the section in such a way that it would appear, even on fairly close observation, that they belong where found in the section. They appear to be next above the basal conglomerate of the Parrsboro formation and, superficially observed, appear to belong in its lower part. The block is bounded on either side, however, by considerable crush zones and is itself so traversed by crush zones as to leave no doubt as to its foreign origin. Furthermore, its fauna does not suggest Pennsylvanian affinities; it contains several species that are either identical with or closely related to the Windsor species, and it is the writer's opinion that it represents some phase of the Windsor. It is not, however, the fauna of the typical Windsor, as developed at Windsor. Fletcher may have been influenced to a considerable degree by this occurrence in his belief that the Parrsboro formation is Windsor in age.

Fletcher's Views on the Windsor, Riversdale-Union Succession.

It thus appears that Fletcher's idea that the Windsor overlies the Riversdale-Union rests on several misunderstandings. Ami has shown that at Arisaig the beds underlying the Windsor which Fletcher thought to be Union are Devonian and a very different formation. At Parrsboro, the beds overlying the Riversdale-Union, which Fletcher thought to be Windsor, are not Windsor at all but a much later formation.

[1] Bull. Geol. Soc. America, vol. 13, p. 533, 1903.

The Sydney section shows conclusively that beds with the Riversdale-Union fauna lie above the Windsor and below the Millstone Grit. It would be gratifying, although it is perhaps not now necessary, if the Riversdale-Union could be shown to overlie the Windsor in the type region of the former about Truro. The areal distribution of the formations on Fletcher's own maps goes far toward demonstrating this.

On the several map sheets around the head of Cobequid bay, Fletcher mapped four terranes, which, according to him, were in ascending order as follows: Riversdale, Union, Carboniferous conglomerate, and Carboniferous limestone or Windsor series. Examination of the maps shows the Carboniferous conglomerate at many points and usually resting on Riversdale and Union. From the distribution of the last two it is evidently an unconformable contact. But at no point is any of the Carboniferous limestone represented on the interior of these conglomerate areas where one should expect them if the limestone overlies this conglomerate. Furthermore, if the succession is as Fletcher claimed, then one should expect a belt of the Carboniferous conglomerate along the contact between areas of Riversdale-Union and the Limestone series. Such is not the case. At not one point is the conglomerate so distributed. The areal distribution of conglomerates and limestone series is such as to leave little doubt but that they are wholly distinct and unrelated formations. The conglomerate appears to be the basal conglomerate of the terrane which unconformably overlies the Riversdale-Union at Parrsboro, the Parrsboro formation.

Is the Riversdale-Union, Parrsboro Unconformity Preserved at St. John, N.B.?

The Little River and Mispec groups, east of St. John, N. B., have been generally acknowledged as the equivalent of the Riversdale-Union series. Unconformably overlying them, a few miles southeast of St. John, is a small patch of conglomerates which have much lower dips and are much less metamorphosed than the underlying beds. When the Little River and Mispec were considered as Devonian in age, this was held to be the conglomerate at the base of the 'Lower Carboniferous'. Recently, Matthew[1] gave the age of the Little River and Mispec as Siluro-Devonian and correlated this conglomerate with the Perry formation (Devonian) of Maine. It appears that the Pennsylvanian age of the Little River-Mispec group and its equivalence to the Riversdale-Union, are now well established, and it seems very probable that the conglomerate unconformably overlying them is the basal part of the Parrsboro formation.

[1] Proc. and Trans. Royal Soc. Canada, 3 ser. vol. 3, sec. 4, p. 73.
See cross-section on plate 4 of article by the same author, on remarkable forms of the Little River group, same vol., pp. 115-125.

REPORT OF THE VERTEBRATE PALÆONTOLOGIST.

(*Lawrence M. Lambe.*)

The past year has been an actively progressive one in connexion with vertebrate palæontology. A field party was maintained during the summer in the valley of Red Deer river, Alberta, a workshop was established in the basement of the east wing of the Museum, and a temporary exhibit was installed in the 'Hall of Fossil Vertebrates' situated on the ground floor of the east wing. Many valuable specimens have been added during 1912 to the rapidly increasing collections of fossil vertebrates, some of which call for early description and illustration. The year's acquisitions include fishes, amphibians, reptiles, and mammals.

Field Work.

A well-equipped party, in charge of Charles H. Sternberg, with three assistants, was in Alberta, on Red Deer river, between Rosebud and Knee Hills creeks for slightly over two months, from the end of July until October 7, the object of the expedition being to secure as representative a collection as possible of the vertebrate fauna of the Upper Cretaceous Edmonton beds exposed in the valley of the river. The success which attended this expedition is most encouraging and augurs well for future work in the same beds.

The party secured the almost complete skeleton of a *Trachodon* or duck-billed, herbivorous, dinosaur which is now being prepared in high relief as a panel mount. As regards this specimen, Mr. C. H. Sternberg reports that 'it was buried in a sandy clay that disintegrated readily at the surface. After laying bare the floor on which it lay we found the entire skeleton in front of the fifth caudal vertebra, except the hind feet which had been washed down the slope. Of these latter many fragments were in the wash, and we believe that nearly the entire series of metatarsals and phalanges are represented and can be restored. This *Trachodon* lay on its right side with the hind legs drawn up and doubled on themselves but with the front ones stretched out at right angles to the column. All the ribs, the pectoral and pelvic arches, and vertebral column were in their natural position except that the ribs had been pressed toward each other and were only about 7 inches apart at their distal ends. The dermal covering is preserved in places on the bones. The distance along the column from the fifth caudal vertebra to the front end of the mouth is 16 feet 5 inches. The length of the skull is 3 feet 1 inch. The tibia measures 3 feet in length and the femur 4 feet. The distance from the top of the ilium to the distal end of the tibia is 7 feet 10 inches. Allowing 2 feet for the hind feet the animal was over 9 feet 10 inches high at the hips.'

The specimen, as it is freed from the enclosing matrix, reveals a wonderful state of preservation. A clear and sharp impression of a large portion of the tuberculated skin to the left of the median line of the back above the hips has been brought to light, as well as many details of structure, among which may be mentioned the regular lattice-like disposition of the ossified tendons in three layers on either side of the neural spines. The fore-feet are fully preserved and supply the exact phalangeal formula. This splendid specimen was obtained near the forks of Mecheche creek about 5 miles from Drumheller, in section 30, township 29, range 19, west of the 4th principal meridian. It is proposed

to mount it in high relief in a panel, when the restored skeleton will have a total length, measured along the curves of the vertebral column, of about 32 feet.

A second specimen of *Trachodon*, larger than the first but not so complete although it includes a magnificent head, was obtained within a short distance of the Wigmore ranch house, and about 1½ mile above Wigmore's ferry, on the east side of Red Deer river.

With respect to this individual Mr. Sternberg has supplied the following field notes: 'Ten feet of the vertebral column lay in position, in sandy clay, including the sixth caudal, sacrum, and dorsals. On the right side there is the complete ischium, femur, tibia, fibula, and hind foot. The hind limb, as is so usual, is flexed at the knee. The anterior cervicals and the skull were found intact but unfortunately the hinder cervicals and anterior dorsals had been destroyed. The skull is 48 inches long, the ischium 54 inches, and the femur 47 inches. The hind leg is 10 feet long giving a height of about 12 feet at the hips. The estimated total length of the animal is about 40 feet.'

This specimen includes, besides the above, the pubic bones and the principal parts (humerus, etc.) of the right fore limb, a sufficient foundation for an open mount of massive proportions.

A third specimen of *Trachodon*, larger than the two above mentioned, was found not far from the second specimen. It is represented by most of the limb bones and by many vertebræ and portions of ribs, but it lacks the head. The femur of this individual has the great length of 4 feet 6 inches.

Mr. Sternberg was fortunate last summer in securing also a number of caudals of a *Trachodon* in place, forming a string of vertebræ 8 feet long which will prove useful in making a complete restoration of the tail.

This collection also includes remains of horned dinosaurs (*Ceratopsia*), and, what is of particular interest, some of the abdominal ribs with the scapulæ and coracoids of one individual of the carnivorous dinosaur *Dryptosaurus* (*Albertosaurus*). As this is the first time that these ribs of the great flesh-eater of the Edmonton formation have been found a description of them will be prepared and published as soon as possible.

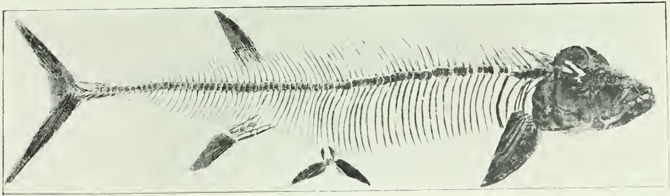
A few bones of *Ornithomimus*, fragments of turtle shells, and fish teeth (*Myledaphus bipartitus*) were also brought in with the above.

Temporary Exhibit of Fossil Vertebrates.

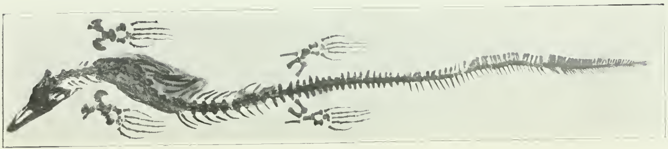
During November and December a temporary exhibit of fishes, amphibians, reptiles, birds, and mammals was placed in the Hall of Fossil Vertebrates. This exhibit, made up for the most part of recently-acquired material, was installed by the end of the year. The fishes include a series of lower and upper Devonian forms from Chaleur bay, and striking examples of *Palæoniscidæ* from the Lower Carboniferous of Albert county, New Brunswick. The amphibians are represented by some of the 'tracks' from the Carboniferous of Nova Scotia formerly on exhibition in the old building. In the reptilian class are examples of the following groups: turtles, ichthyosaurs, mosasaurs, herbivorous and carnivorous dinosaurs, marine crocodiles, and flying reptiles. The mammals include representatives of a number of orders and sub-orders. Some of these, as with the reptiles, are impressive from their size, quite apart from their scientific value, and attract public interest. The series illustrating the evolution of the 'horse' and 'elephant' are particularly instructive.

The various specimens are shown with descriptive labels, couched in popular language, and tables of the animals characteristic of the various geological periods assist in explaining faunal succession from an evolutionary standpoint.

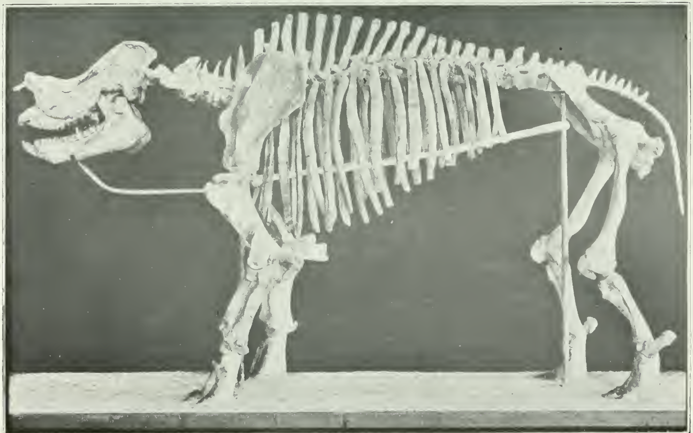
Plate I



PLATECARPUS



PORTHEUS



TITANOTHERIUM

Among the recent additions to the fossil vertebrate exhibit may be mentioned three specimens in particular which from their size and imposing appearance claim special notice. These consist of a fine panel mount, in low relief, of the Cretaceous fish *Portheus molossus;* the Cretaceous marine reptile *Platecarpus coryphæus*, also shown as a panel mount; and a specially striking open mount of a Titanotherium, representing in the collection the race of huge, plant-eating, hoofed mammals which flourished in the country east of the Rockies during Oligocene time. These three specimens are shown in the accompanying photographic reproductions.

Portheus molossus, Cope, was a large, predaceous fish which lived in the Cretaceous sea at the time the Niobrara beds were being deposited. It attained a length of 15 feet, the total number of vertebræ numbering about eighty-five. Its strong, compressed, conical teeth are fixed in sockets in the margins of the jaws in irregular series. The pectoral and pelvic fins have broad anterior rays, and the dorsal fin is set back not far in advance of the deeply forked and remarkably symmetrical tail. This fish was related to the existing Tarpon of the Florida coast.

The specimen (Plate I) is a composite one and was collected by C. H. Sternberg and party from the Niobrara Cretaceous chalk beds of Gove county, Kansas, and mounted by C. M. Sternberg.

The great swimming reptile *Platecarpus coryphæus*, Cope, belonged to the group of Mosasaurs which lived throughout the Cretaceous period with a wide distribution, and dominated the seas on the decline of the ichthyosaurs and plesiosaurs. In Platecarpus the head was flattened above and triangular in outline. The slender body, ending in a very long, laterally compressed tail, and the presence of two pairs of paddle-shaped limbs, indicate that the animal was probably a powerful and rapid swimmer.

This splendid specimen (Plate I) is 20 feet 6 inches long; the head and the entire vertebral column belong to one individual, while the paddles are from another of corresponding size. The head is particularly well preserved and is mounted in high relief. The specimen was collected by George F. Sternberg in 1911 from the Niobrara (Cretaceous), south of Smoky Hill river, 6 miles east of Keystone, Logan county, Kansas, and was mounted by Charles H. and G. F. Sternberg.

The titanotheres lived in Eocene and lower Oligocene times and seem to have been peculiar to the continent of North America. They were primitive, hoofed, herbivorous mammals which rivalled the elephant in size, and belonged to the odd-toed group of which the tapirs, rhinoceroses, and horses are living examples. They inhabited low-lying stretches of country and lived on succulent plants.

In *Titanotherium* the skull was long and shaped somewhat like that of a rhinoceros. On the nose were two horns set transversely not far in advance of the eyes which were placed far forward.

The specimen here shown (Plate II) is 11 feet long from the snout to the drop of the tail, and 6 feet 6 inches high measured to the top of the highest neural spine (hump). The skull, vertebral column, shoulder blades, pelvis, ribs, and most of the leg bones belong to one individual, making this skeleton one of the most complete of an Oligocene titanothere known. The specimen was collected by C. H. Sternberg from the lower Oligocene of Sage creek, Converse county, Wyoming, in 1911, and was set up as a free or open mount by C. H. Sternberg and his son G. F. Sternberg in the museum of the Geological Survey in the early part of 1912.

Establishment of a Vertebrate Palæontological Laboratory.

The establishment of a vertebrate palæontological laboratory and the engagement of Charles H. Sternberg and his son Charles M. Sternberg as preparator-collectors, are forward steps of great importance in the history of the vertebrate palæontological work of the Geological Survey.

The laboratory occupies a space roughly 50 feet by 32 feet in the extreme eastern basement of the building. At the end of the year plans were well under way for its equipment with modern labour-saving appliances of the latest pattern with a view to placing it in the front rank of up-to-date laboratories of a similar character. With its completion the preparator-collectors will be able to work under the most favourable conditions and to produce results in preparing and mounting specimens, etc., which will be a credit to the Geological Survey.

Both Mr. Sternberg and his son are trained collectors and preparators of fossil vertebrates. The former especially has a world-wide reputation as a skilled collector of many years' experience, having devoted his life to work of this character.

Under these improved conditions field work can now be more vigorously prosecuted with a wider scope and it will be possible with the facilities to be provided in the laboratory to prepare and preserve collections for study and exhibition purposes by the most approved methods.

Office Work.

Early in the year some time was given to the preparation of a Bibliography of Canadian Zoology (exclusive of entomology) for 1911, which was presented at the annual meeting of the Royal Society of Canada in Ottawa in May and accepted for publication in the Transactions of the Society.

Also, reports were prepared on the following:—

Fish-scales from a core, at depths of 2,070-2,080 feet, received by Mr. E. D. Ingall from a gas well at Taber, Alberta. Species identified and geological horizon (Benton, Cretaceous) indicated.

Fossil corals, collected by Mr. D. D. Cairnes during the summer of 1911, on the boundary between Yukon and Alaska, near the Arctic circle; indicating a Silurian horizon with faunal relationship to the Silurian of Beechey island.

Throughout the year considerable time was given to library and general museum affairs, and all the meetings of both the Museum and Library Committees were attended.

Additions to the Vertebrate Palæontological Collections during 1912.

Collected by Officers of the Geological Survey

Bell, Walter, A.—Microsaurian remains (field collection of 1911) from Joggins, Nova Scotia, in the Coal Measures. From beds Nos. 367, 352, 247, and 198 of Division IV of Logan's section. Acc. No. 39.

The remains occurred in carbonaceous matrix in the base of casts of trunks and stumps of Sigillaria.

Sternberg, Charles H., and party.—A very large collection of vertebrate remains, principally dinosaurian, from the Edmonton formation (Upper Cretaceous), Red Deer river, Alberta. Acc. No. 62.

This collection includes the following:—

A splendid specimen of *Trachodon* (duck-billed dinosaur) which includes the entire skeleton from the snout to the fifth caudal vertebra, back of which the tail is missing. Discovered by C. M. Sternberg on Mecheche creek which empties into Red Deer river opposite Drumheller.

Another *Trachodon*, larger than the above, represented by the head, most of the vertebral column in advance of the sixth caudal vertebra, with the principal bones of the right limbs. Found by L. Sternberg, on the east side of Red Deer river, between Wigmore ferry and the Wigmore ranch.

A third specimen of *Trachodon*, larger than the above two, represented by the principal bones of the skeleton but lacking the head.

A section 8 feet long, of the caudal vertebræ of a trachodont.

A large number, between 300 and 400, of dissociated bones of trachodonts.

Parts of the skull (rostral bone, nasals, nasal horn-core, supraorbital horn-core, etc.) of a horned dinosaur?*Triceratops*, and horn-cores, etc., of other individuals.

Some of the abdominal ribs with the two scapulæ and coracoids of one individual of the carnivorous dinosaur *Dryptosaurus* (*Albertosaurus*).

Dissociated teeth of *Dryptosaurs.*

Dissociated vertebræ of *Champsosaurus.*

A few dissociated bones (vertebræ, phalanges, etc.) of *Ornithomimus.*

Fragments of carapace and plastron of two species of turtles belonging apparently to the genera *Aspideretes* and *Basilemys.*

Teeth of *Myledaphus bipartitus*, Cope, a marine fish supposed to be related to the rays.

Presented.

Craig, J. D., Ottawa, Ont.—One large upper molar tooth of mammoth, from near Lapierre house, Bell river, Yukon. Pleistocene. Cat. No. 8366. (Through D. D. Cairnes.)

Brownjohn, N., Drumheller, Alta., (Postmaster at)—The upper back portion with horn-cores, of the skull of *Bison* sp. found 20 feet beneath the bed of Red Deer river in excavating for the abutment of the Canadian Northern Railway bridge near Drumheller. July, 1911. (Through C. H. Sternberg.) Cat. No. 8186.

Lett, R. C. W., Grand Trunk Pacific Railway, Winnipeg, Man.—Upper molar tooth of mammoth (Cat. No. 8367), and a rib (Cat. No. 8368) presumably of mammoth, from Pleistocene deposits in Circle City district, Alaska.

Criddle, Stuart, Treesbank, Man.—The skull, with lower jaw, of a large wolf (Cat. No. 8369), and the horn-cores, with portion of the upper back part of the skull, of *Bison crassicornis*? Richardson. (Cat. No. 8370.) From sandhills, about 14 miles north of Treesbank. ? Pleistocene.

Purchased.

Platecarpus coryphæus, Cope.—Complete skeleton mounted in slab, the paddles being from a second individual. Niobrara (Cretaceous), south of Smoky Hill river, 6 miles east of Keystone, Logan county, Kansas, U.S.A., Cat. No. 8163. Collected by George F. Sternberg.

Specimens from the Niobrara (Cretaceous) of Gove county, Kansas, U.S.A. Collected by George F. Sternberg. Acc. No. 57. The collection includes the following:—

One specimen of *Tylosaurus proriger*, Cope, 18 feet long.
Two skulls of *Platecarpus coryphæus*, Cope.
Skull and part of trunk of *Portheus molossus*, Cope.
Tortoise.
Shark's tail, with dorsal fin, 7 feet long.
Several small fishes.

A collection of vertebrates from the Niobrara Cretaceous of western Kansas, and from the Oligocene of Converse county, Wyoming, Acc. No. 38.

The Cretaceous specimens were collected by George F. Sternberg in 1911 and include:—

Anogmius polymicrodus, Stewart. Skull, from north of Tweed, Gove county, Kansas, U.S.A. Cat. No. 8155.
Pachyrizodus, skull, from same locality. Cat. No. 8157.
Empo, skull and trunk region, from same locality. Cat. No. 8156.
Ichthyodectes anaides, Cope. Skull, from same locality. Cat. No. 8158.
Portheus molossus, Cope. Skull and portion of trunk, from same locality. Cat. No. 8153.
Portheus molossus, Cope. Skull, from same locality. Cat. No. 8152a.
Gillicus arcuatus (Cope). Skull, from same locality. Cat. No. 8153.
Tylosaurus dyspelor (Cope). Skull, from Hackberry creek, near Gove county, Kansas. Cat. No. 8162.
Pteranodon ingens, Marsh. Wing bones, from Sampson's pasture, Hackberry creek, Gove county, 13 miles south of Quinter, Kansas. Cat. No. 8167.
Nyctosaurus gracilis, Marsh. Wing bones from same locality. Cat. No. 8168.

The specimens from the Oligocene were collected by Charles H. and C. M. Sternberg from Seaman's old ranch, Sage creek, a branch of Old Woman creek, Converse county, Wyoming, and include the following:—

Stylemys nebrascensis, Leidy. A number of specimens.
Specimens of *Testudo* which include probably undescribed species.
Parahippus? material.
Diceratherium sp., complete series of molars and premolars, and other specimens.
Specimens of Cameloid (genus?).
Oreodont material (genera?).
Rodents.
Nothocyon?
Undetermined mammals.

As the above collection (Acc. No. 38) has not yet been studied the determinations are tentative only.

Skull of *Triceratops*, without the frill, from the Laramie Cretaceous of Niobrara county, Wyoming, U.S.A. Collected by Charles H. Sternberg. Acc. No. 58.

Titanotherium. Skeleton of one individual, in open mount. Collected by Charles H. Sternberg from Titanotherium beds (Lower Oligocene), Sage creek, Converse county, Wyoming, U.S.A. Cat. No. 8184.

Mammalian remains from the Oligocene at South Brush creek, Niobrara county, Wyoming, U.S.A., collected by C. M. Sternberg. Acc. No. 56. The collection includes:—

Excellent skulls of *Oreodon*, with parts of skeletons of the same.
Skull, with mandible, of *Elotherium.*
Jaws of *Elotherium.*
Mandible of dog (?*Amphicyon*).
Three specimens of Testudo.

Molar tooth of *Mastodon americanus* (Cuvier), from Sulphur creek, near Dawson, Yukon. Pleistocene. Cat. No. 8060.

This tooth is figured by Charles W. Gilmour in his 'Smithsonian Exploration in Alaska in 1907 in search of Pleistocene Vertebrates,' Smithson. Miscel. Coll., vol. LI, Washington, D.C., 1908, p. 30, pl. VIII, fig. 2.

A small molar tooth of *Mastodon americanus* (Cuvier), from Pleistocene deposits in Dawson mining district, Yukon. Cat. No. 8147.

A well preserved mandible, without teeth, of *Mastodon americanus* (Cuvier) from Pleistocene deposits just below Lower Discovery claim in Dominion creek, Dawson mining district, Yukon. Cat. No. 8138.

Mandible of mammoth, holding one molar in each ramus, from Pleistocene deposits, Dawson mining district, Yukon. Cat. No. 8136.

Two lower molars of Mammoth from Pleistocene deposits just below Lower Discovery claim in Dominion creek, Dawson mining district, Yukon. Cat. Nos. 8139 and 8140.

A small tusk presumably of mammoth from Pleistocene deposits on claim No. 1, 80 Pup, Hunker creek, Dawson mining district, Yukon. Cat. No. 8143.

Upper molar of mammoth from Pleistocene deposits, just below Lower Discovery claim in Dominion creek, Dawson mining district, Yukon. Cat. No. 8141.

Upper molar of mammoth from Pleistocene deposits on Claim No. 50 below Discovery claim in Sulphur creek, Dawson mining district, Yukon. Cat. No. 8137.

Upper molar of mammoth from Pleistocene deposits on Claim No. 1, 80 Pup, Hunker creek, Dawson mining district, Yukon. Cat. No. 8142.

Bison crassicornis, Richardson. Two specimens, each consisting of the upper back portion of the skull with horn-cores sheathed with horn, from Pleistocene deposits on Claim No. 52, below Discovery claim, Bonanza creek, Dawson mining district, Yukon. Cat. Nos. 8144 and 8145.

Bison crassicornis, Richardson. One specimen consisting of the upper back part of the skull with horn-cores sheathed with horn, from Pleistocene deposits of Dawson mining district, Yukon. Cat. No. 8146.

REPORT OF THE INVERTEBRATE PALÆONTOLOGIST.

(*E. M. Kindle*)

Field Work.

The field season of 1912 was well advanced before I assumed the duties of Invertebrate Palæontologist. I reported for duty at Ottawa August 1, and began field work a few days later, going first to southern Ontario where about eight days were spent in the study of some of the more important Devonian sections. The time spent in this district was devoted chiefly to the horizons of the Oriskany sandstone and the Ohio shale. The remainder of the field season was devoted to a study of the Devonian and Silurian section of Manitoba.

Office Work.

In the office I have had the assistance of Miss A. E. Wilson, who has rendered very efficient aid in the various routine museum duties and in connexion with cataloguing incoming collections. A locality and horizon card catalogue of all current collections is being prepared which will be extended as rapidly as possible to all of the old collections. This will make possible easy and speedy reference to all of the collections. As other duties have permitted, work has been continued by Miss Wilson on the catalogue of types of the Museum.

Mr. M. Y. Williams has been occupied in the office, chiefly with the determination of the collections made by him from the Silurian rocks of the Manitoulin Island district and with the preparation of a report on the formations represented.

A considerable portion of my time in the office has been devoted to the preparation of special reports on collections of fossils made by members of the staff. Work on the collections, the preparation of a summary report, and two papers for publication in scientific journals occupied the remainder of my time in the office. In addition to the collections obtained by the field geologists in the course of their work, various collections for the Museum have been acquired through donation or purchase. Arrangements have been made for the acquisition of other collections by exchange. The source of each of the several collections received is indicated in the following memoranda concerning them:—

Collections Reported Upon.

Allen, J. A.—A collection of fossils from Fossil mountain, Alta. Access. No. 96.
Cairnes, D. D.—A large collection from the Alaskan boundary. Access. No. 98.
Clapp, C. H.—A collection of Tertiary gasteropods from the Metchosin volcanics from Albert head, Vancouver island, B. C. Access. No. 90.
A small collection from Graham island, etc., B. C. Access. No. 109.
Drysdale, C. W.—Fossils from Kamloops district, B. C. Access. No. 102.
Foerste, A. F.—A collection of Black River and Silurian fossils from Manitoulin and Lacloche islands; bryozoa from Meaford, Ont., and Richmond fossils from the Lake St. John region, Quebec. Access. No. 92.
Kindle, E. M. and
McLean, A.—Fossils from the Devonian, Silurian, and Ordovician of northwestern Manitoba. Access. No. 99.

Lawson, A. C.—Cambrian fossils from Steeprock lake, Ont. Access. No. 111.
Leach, W. W.—Small lots of fossils from Blairmore, Frank, and the Livingstone range, Alta. Access. Nos. 100 and 108.
Malloch, G. S.—A collection of fossils from Groundhog coal basin; from the vicinity of Cluayetz lake and McDonald creek, B. C. Access. No. 103.
McConnell, R. G.—A small collection of fossils from Bulkley river, B. C. Access. No. 101.
Schofield, S.—A small lot of corals from Gold creek, B. C. Access. No. 91.
Williams, M. Y.—A collection of Devonian fossils from Thedford, Ont., and Silurian from Manitoulin island, Cabots head, and the vicinity of Collingwood, Ont. Access. No. 110.

Additions to the Invertebrate Palæontological Collections during 1912.

Collected by Officers of the Geological Survey.

Allen, J. A.—A collection of fossils from Fossil mountain, Alta. Access. No. 96.
Baker, M.—Fossils from Gaspé, Que. Access. No. 95.
Cairnes, D. D.—Two large collections of fossils from the Alaskan boundary. Access. Nos. 97, 98.
Clapp, C. H.—A collection of Pleistocene fossils from Cordova sands and gravels, east shore of James island, B. C.; and from the Maywood clays, one-half mile south of Lost lake, Victoria district, Vancouver island, B. C. Access. No. 80.

Fossils from the Sooke and Carmanah formations of the west coast of southern Vancouver island, B. C. Access. No. 83.

A collection from the Sutton formation of the Vancouver group, south shore of Cowichan lake, Vancouver island. Access. No. 84.

One lot from the Nanaimo series from the Nanaimo sheet, B. C. Access. No. 85.

Tertiary gasteropods from the Metchosin volcanics from Albert head, Vancouver island, B. C. Access. No. 90.

Fossils from Graham island and vicinity, B. C. Access. No. 109.

Drysdale, C. W. —Fossils from Kamloops district, B. C. Access. No. 102.
Foerste, A. F.—A collection of Black River and Silurian fossils from Manitoulin and Lacloche islands, bryozoa from Meaford, and Richmond fossils from region of Lake St. John, Que. Access. No. 92.
Goldthwait, J. W.—A small lot of fossils from the Tertiary of Hemmingford and Rivière-du-Loup, Quebec. Access. No. 88.
Kindle, E. M. and
McLean, A.—Fossils from the Devonian, Silurian, and Ordovician of northwestern Manitoba. Access. No. 99.
Leach, W. W.—A collection of fossils from the Benton formation from range 4, west of the 5th meridian, Alta.; from the Devonian of Kathead mountains, Alta.; from the Kootenay of range 3, west of the 5th meridian, Alta. Access. No. 81.

Fossils from the Jurassic near Fernie, B. C. Access. No. 82.

Small lots of fossils from Blairmore, Frank, and the Livingstone range, Alta. Access. Nos. 100 and 108.

Malloch, G. S.—Fossils from Groundhog Coal Basin; from the vicinity of Cluayetz lake and McDonald creek, B. C. Access. No. 103.
McConnell, R. G.—A small collection of fossils from Bulkley river B. C. Access. No. 101.

Nichols, D. A.—A collection of 11 fossils from loose Mississippian limestone from the slide at Frank, Alta. Access. No. 78.

Schofield, S.—A small lot of corals from Gold creek, B. C. Access. No. 91.

Sternberg, C. H.—A collection of lamellibranchs from the Edmonton series on the Red Deer river, Alta. Access. No. 104.

Williams, M. Y.—A collection of Devonian fossils from Thedford, Ont., and Silurian fossils from Manitoulin island, Cabots head, and the vicinity of Collingwood, Ont. Access. No. 110.

Presented.

Empey, W. G.—A small collection of Utica fossils from Hammond, Ont. Access. No. 94.

Grant, Col. C. C.—A collection of Silurian fossils from Hamilton, Ont. Access. No. 93.

Mercier, P.—A specimen of *Cyathophyllum pennanti* Billings, collected at L'Anse au Gascon, Bonaventure Co., Que. Access. No. 86.

Petrick, A.—Two specimens of *Viviparus? prudentia* White, from the Upper Cretaceous at Bassano, Alta. Access. No. 89.

Purchased.

Neill, Mrs. M., Hamilton, Ont.—A collection of fossils from Ordovician drift and Silurian in the neighbourhood of Hamilton, Ont.; from the Guelph of Durham, Ont., and vicinity; and some Devonian from Hagersville, Ont. Access. No. 79.

PALÆOBOTANY.

(*W. J. Wilson.*)

A considerable portion of the year was spent in numbering and cataloguing collections of fossil plants which have been identified and named. Among these were Mr. L. M. Lambe's Oligocene plants from British Columbia which were continued from last year, and those collected in 1911 by Messrs. D. B. Dowling, G. S. Malloch, J. Keele, and L. Reinecke. Names were attached to two boxes of specimens from the Fern Ledges, St. John, and Lepreau, N. B., as identified by Dr. G. F. Matthew.

In the Summary Report for 1911, page 359, reference was made to two leaves collected by Mr. Leopold Reinecke in the Beaverdell district, British Columbia, as being generically new. In general appearance these leaves resemble those of an herbaceous plant, and in form, venation, and the peculiar dentate margins they approach nearest the living genera *Pilea* and *Urtica* in the Nettle family. Fragaria is another genus to which the broad form bears a strong resemblance. I have figured and described them under the name *Lebephyllum reineckei* sp. nov. in a bulletin of this department now in press.

In 1908 collections of fossil plants were made by the writer at Keiths beach on the northwest shore of Kennebecasis island, Saint John county, N. B.; and from Moosehorn brook 2 miles southwest of Norton, Kings county, N. B.; and the following year from Robertson brook, Elgin, Albert county, N. B. The latter is 20 miles west of the 'Albert Mines'. During the year these plants were in part studied and named.

At Kennebecasis island *Lepidodendron corrugatum*, Dawson, is by far the most common plant. One bed of grey sandstone about 8 inches thick is packed full of specimens of this species of different sizes and various states of preservation. Some of these specimens agree perfectly with Sir William Dawson's description and figures, and there seem to be intermediate forms which fill the gap between the extremes, so that it is doubtful if there is more than one species in my collection from this locality. From a collection from this place made by Dr. R. W. Ells in 1906, Dr. G. F. Matthew, however, named *Lepidodendron corrugatum, L. gaspianum, L. chemungense, L. sternbergii, L. aculeatum, and L. rimosum*[1]. A small collection of the plants from Kennebecasis island was sent to Dr. David White, of Washington, who writes of Lepidodendron as follows: 'The examination of the fragments of Lepidodendron shows more closely than I had before seen the extremely close relation of Dawson's *Lepidodendron corrugatum* with the plant from the Pocono of Virginia, published by Meek as *Lepidodendron scobiniforme*. Certainly these species are difficult to distinguish, if, indeed, they are not identical.'

Detached pinnules of *Aneimites acadica*, Dawson, were found at Keiths beach but were not common, also fern stems in great abundance some of which are large and branching. There are other specimens which may probably be referred to *Cordaites*. Besides the above there are two plants which are evidently new to the New Brunswick flora. One has very narrow frequently dissected pinnules and is somewhat comparable to *Sphenopteris vespertina*, D. White. The other has round pinnules and is probably also a *Sphenopteris*.

As to the age of the Kennebecasis Island beds Dr. White says: 'The plant

[1] Trans. Roy. Soc. of Canada, third series, 1907–1908, vol. I, sec. 4, p. 196.

fragments you sent represent, almost without doubt, a basal Lower Carboniferous flora, which, though varying as to species in the different regions of the northern hemisphere, is extraordinarly similar in its meagre composition throughout. I have no hesitation in referring your plants to that stage.' Dr. Matthew, on the other hand, refers these rocks to the Upper Devonian. *Lepidodendron corrugatum* and *Aneimites acadica* were both found in the collections from Moosehorn brook and Elgin, and form a large part of the flora. At Moosehorn brook there are many splendidly preserved specimens of *L. corrugatum*, some having the leaves attached as shown in Sir William Dawson's figures. *Aneimites acadica* is only found in detached pinnules at all these localities. From an examination of the contained fossil plants it seems reasonably certain that the rocks at Kennebecasis island, Moosehorn brook, and Elgin are of the same age as the Horton series of Nova Scotia which Sir William Dawson, Dr. David White, and Mr. R. Kidston have placed in the Lower Carboniferous. Judging from the flora, it is further evident that these localities are older than the rocks along the north shore of the Bay of Fundy, at McCoy head, Gardner creek, Tynemouth creek, and Cape Enrage from which considerable collections have been made. These have not been studied carefully, but a cursory examination shows that they are probably of Pottsville age.

Chas. W. Drysdale of this department brought in a collection of about 80 fragmentary specimens of fossil plants from the Pimainus hills north of Spence bridge on the Thomson river, B. C. The following genera and species were named:—

Nilssonia cf. *N. schaumburgensis* (Dunker).	*Cladophlebis* cf. *C. browniana.* (Dunker).
Taeniopteris cf. *T. orovillensis* Fontaine.	*Cladophlebis* cf. *C. falcata montanensis* (Font.)
Taeniopteris or *Oleandra*	*Cladophlebis* sp.
Sequoia reichenbachii, Heer.	*Oleandra* sp.
Podozamites lanceolatus, L. and H.	*Equisetum*?
Podozamites cf. *P. graminaefolia.*	*Sagenopteris* cf. *S. paucifolia* (Phill.) Ward.
Podozamites sp.	*Sphenolepidium* sp.

These plants are probably Kootenay, but some of them have a Jurassic aspect. As the rocks in which they were found had been mapped as Miocene a change to the Lower Cretaceous was of such importance that it was thought advisable to send the fossils to Dr. F. H. Knowlton, Washington, for examination. Dr. Knowlton made some minor changes in my determinations and confirmed the opinion that the Pimianus hills are Kootenay with decided Jurassic affinities. The above list of plants is from the corrected list returned by Dr. Knowlton.

G. S. Malloch brought in another small but interesting collection of well-preserved fossil plants from the Groundhog coal basin, Upper Skeena river, B. C. These were examined and in part named and then forwarded to Dr. F. H. Knowlton, of Washington, who kindly revised my determinations and added several species to my list. The following genera and species are from the list as corrected by Dr. Knowlton:—

Ginkgo sibirica Heer.	*Cladophlebis virginiensis* Font.
Nilssonia nigracollensis Wieland.	*Cladophlebis falcata* Font.
Nilssonia mediana (Leck.)	*Podozamites lanceolatus* (L. and H.)
Nilssonia schaumburgensis (Dunk.) Nath.	*Zamites montana* Dawson.
Nilssonia sp.	*Oleandra graminaefolia* Knowlton.
Acrostichopteris pluripartita (Font.) Berry	*Thyrsopteris* sp.
Cephalotaxopsis ramosa Font.	

Dr. Knowlton says 'that one specimen is absolutely indistinguishable from *Acrostichopteris pluripartita* (Font.) Berry as figured in Md. Geol. Surv. Lower Cretaceous, 1911, pl. XXIV, fig. 6. It has heretofore been known only from the Patuxent formation of Maryland and Virginia. Three specimens are not to be distinguished, at least from the fragments present, from *Nilssonia mediana* (Leck.) a well known Jurassic species. This is the first time, so far as I know, that it has been reported from higher beds. The other forms are the ordinary species usually associated in the Kootenay, and there can be no reasonable doubt as to the correctness of referring them all to the Kootenay.'

In 1911, Mr. Malloch collected from the same locality the following species not in the above list: *Cladophlebis fisheri* Knowlton. *Nilssonia parvula* (Heer) Font. *Equisetum phillipsii* (Dunk) *Baiera multinervis* Nath. and *Gleichenia* sp.

W. W. Leach brought in over 60 specimens of fossil plants from the Maple Leaf coal mine near Bellevue, Alta., and a few from near Blairmore, Alta. These were also referred to Dr. Knowlton, who writes that the plants from the Maple Leaf mine practically represent but one species which he thinks is new. He says the fruit indicates that they belong to *Dicksonia*, but some of them suggest *Coniopteris burejensis* (Zalessky) Seward. A specimen of *Podozamites lanceolatus* (L. and H.) and a *Nilssonia*? were also found near Bellevue. *Dicksonia montanensis* Font. and an obscure *Sagenopteris*? were noted among the Blairmore material. Dr. Knowlton refers these collections to the Kootenay.

C. H. Clapp collected two fossil plants on Graham island, B. C. One is a specimen of wood of which no sections have been made. 'The other is a fragment of a dicotyledonous leaf but indeterminable.'

A small collection of fossil plants was made by D. D. Cairnes from the Sourdough mine, Coal creek, Yukon territory. They were reported on by Dr. F. H. Knowlton who recognized the following species:—

Osmunda heerii, Gaud.	*Juglans acuminata* Al. Br.
Equisetum cf. *E. arcticum*, Heer.	*Corylus*? sp. fragments.
Sequoia langsdorfii (Brong) Heer.	*Betula* cf. *B. Brongniarti*, Ett.

Dr. Knowlton writes: 'Although the material is not extensive or very well preserved it is fortunately sufficient to fix the age as Kenai.'

Additions to the Palæobotanical Collection during 1912.

Collected by Officers of the Geological Survey.

Cairnes, D. D.—26 specimens of fossil plants from the Sourdough mine, Coal creek, Yukon territory. Accession No. 7.

Clapp, C. H.—2 specimens of fossil plants from the Haida formation. Graham island, B. C. Accession Nos. 40 and 41.

Drysdale, Chas. W.—156 specimens of fossil plants from six different localities in the Kamloops district, B. C. Accession Nos. 3 to 6 inclusive and 8.

Leach, W. W.—73 specimens of fossil plants from five different localities from near Bellevue and Blairmore, Alta. Accession Nos. 35 to 39 inclusive.

Malloch, G. S.—36 specimens of fossil plants from twelve different localities in the Groundhog coal basin, head of the Skeena river, B.C. Accession Nos. 22 to 28 and 30 to 34 inclusive.

1 specimen from mountains south of Blackwater lake. Accession No. 29.

Sternberg, Chas. H.—153 specimens of fossil plants and wood from five localities in the vicinity of Drumheller, Red Deer river, Alta. Accession Nos. 9, 10, 11, 13, 20.

Sternberg, C. M.—90 specimens of fossil plants (leaves and cones) from 2 miles southeast of Drumheller to right of road to Acme, Red Deer river, Alta. Accession No. 12.

Presented.

Evans, W. B.—4 specimens of Carboniferous plants from the Rothwell Coal Company's mine, Minto, Sunbury county, N.B. Accession No. 1.

Purchased.

553 specimens of fossil plants (dicotyledonous leaves) Dakota group from four localities in Ellsworth county, Kansas, U.S.A. Accession Nos. 14 to 17 inclusive.

26 specimens of fossil plants and fruit (Ficus) from Converse county, Wyoming, U.S.A. Accession Nos. 18 and 21.

100 specimens of Tertiary plants from Florissant, Colorado, U.S.A. Accession No. 19.

MINERALOGY.

(Robt. A. A. Johnston.)

The work performed in this section has been of the same general character as that undertaken in previous years. Over four hundred specimens have been examined and reported upon. A detailed examination of a specimen of prehnite from Adams sound, Admiralty inlet, Franklin, has been completed. The specimen was collected by Captain J. E. Bernier during his Arctic Expedition of 1910-11. The result of this examination will appear in the forthcoming issue of the Museum Bulletin. A new annotated list of Canadian mineral occurrences is in course of preparation.

Work Performed by Members of the Division.

Mr. Stanley P. Graham.

Up to the date of his resignation at the end of February, Mr. Stanley P. Graham rendered excellent service in the work on the index of Canadian minerals.

Mr. A. T. McKinnon.

Mr. McKinnon has continued to render unremitting and conscientious service in the duties that have been entrusted to him. In addition to the collection and distribution of material for the educational collections, he has also been engaged to some extent in museum work. During the season of 1912 he was in the field from June 3 to October 1, during which time he collected over twelve tons of material in the Provinces of Ontario, Quebec, New Brunswick, and Nova Scotia for the educational collections, besides a large series of museum specimens. In connexion with this work many gentlemen have rendered most gratifying assistance both in the way of advice and supplying, free of charge, very considerable quantities of material.

The thanks of the Survey are specially due to the following: Mr. Justinien Coulombe, Bay St. Paul, Que.; Mr. C. J. Osman, and Mr. F. M. Thompson, Hillsboro, N.B.; Mr. James Robertson, Albert Mines, N.B.; Mr. James D. Maxwell, Springhill Mines, N.S.; Mr. W. F. Parsons, M.E., Middleton, N.S.; Mr. Daniel L. MacLeod, Torbrook, N.S.; Mr. E. A. Collins, Kingston, Ont.; Mr. J. P. Kelly, Sulphide, Ont.; Mr. S. B. Wright, Delora, Ont.; Mr. Wilson Bailey, Madoc, Ont.; Mr. Donald Henderson, Madoc, Ont.; Mr. Thomas Morrison, Bancroft, Ont.; Mr. E. B. Clarke, Craigmont, Ont.; Mr. Wilson Mackay, Burgess, Ont.; Mr. J. A. Kacher, Moose Head Mine, Blind River, Ont.; Mr. James H. Reid, Dean Lake, Ont.; Mr. R. W. Seelye, Manager, The Lake Superior Corporation, Sault Ste. Marie, Ont.; Mr. A. Hasselbring, Supt. of Mines, Michipicoten Mining Division, Ont.; Mr. A. A. McKay, Helen Mine, Ont.; Mr. James Bartlett and Mr. W. Goodwin, Magpie Mine, Ont.

Collections have been distributed by provinces as follows:—

	Grade 1.	Grade 2.
Alberta	1	..
British Columbia	3	1
Manitoba	1	1
New Brunswick	..	4
Nova Scotia	3	15
Ontario	15	10
Quebec	11	8
Saskatchewan	1	1
Foreign	1	..

Additions to the Mineral Collections During 1912.

The following additions have been made to the Canadian section of the mineral collections:—

Presented.

Mr. F. R. Aufhammer, Renfrew, Ont.—Molybdenite from Brougham, Renfrew county, Ontario.

Captain J. E. Bernier, Quebec, Que.—Prehnite from Adams sound, Admiralty inlet, Baffin island, Franklin.

Mr. Glen Campbell, Dawson, Man.—Gold ore from Manigotagan river, Lake Winnipeg, Manitoba.

Mr. J. A. Leamy, Ottawa, Ont.—Native silver from near Wallace, Similkameen mining division; blister copper from the smelter at Grand Forks, British Columbia.

Mr. J. McEvoy, Toronto, Ont.—Coal from above Groundhog mountain, Skeena river, British Columbia.

Mr. H. M. Nelson, Ottawa, Ont.—Pyrargyrite and cobaltite from Cobalt, Ontario.

Mr. Racey, Rossland, B.C., per Mr. R. W. Brock.—Fluorite and apophyllite from the Centre Star mine, Rossland, British Columbia.

Mr. J. Rochester, Vancouver, B.C., per Mr. R. W. Brock.—Specimen illustrating vein formation from Kispiox, Skeena river, British Columbia.

Mr. A. S. Rosenroll, Wetaskiwin, Alberta.—Coal from section 10, township 46, range 18, west of the 4th meridian (Bawlf Collieries) Alberta.

The Honourable W. T. White, Ottawa, Ont.—One ten dollar and one five dollar gold piece—first of the Canadian gold coinage issued from the Royal Mint, Ottawa.

Mr. C. W. Willimott, Ottawa, Ont.—Large mass of pink and green tourmaline from Wakefield, Ottawa county, Quebec.

Mr. Bush Winning, Ottawa, Ont., per A. T. McKinnon.—Zircon and sphene from the Little Rapids mine, Portland East; gummite from the Villeneuve mine, Villeneuve, Ottawa county, Quebec.

Collected by Officers of the Department of Mines.

Mr. D. D. Cairnes—Amber in coal from the Sourdough mine, Coal Creek, Yukon.

Mr. C. H. Clapp—Series of nineteen rock specimens from the south end of Vancouver island, B.C.

Mr. L. H. Cole—Selenite crystals from Merritt, Nicola Mining division, British Columbia.

Mr. D. B. Dowling—Coal from Jasper Park Collieries and Folding mountain; amber in lignite from Shunda creek, Alberta.

Mr. E. R. Faribault—Sillimanite from Eastern Head, Liverpool bay, Queens county, Nova Scotia.

Mr. R. Harvie—Three samples of marble from Bolton; schistose talc from Bolton; magnetite crystals on chlorite rock from Bolton; actinolite from Brome; fuchsite from Brome, Brome county, Quebec.

Mr. J. Keele—Bentonite from Quilchena, Nicola Mining division, British Columbia.

Mr. W. W. Leach—Copper ores from Howson creek, Goat creek, Morice river, and Starr creek; coal from Goat creek, Telkwa river, Omineca Mining division, British Columbia; tuff from Crowsnest volcanoes, York creek, Alberta.

Mr. O. E. LeRoy—A series of thirty-one specimens of ores and rocks from the Ainsworth, Greenwood, Nelson, and Slocan Mining divisions, scheelite from the Poorman mine; gold ore from the Athabaska mine, Nelson Mining division; lead crystals from the Trail smelter; wolframite from Ashnola river, Similkameen Mining division—all in the Province of British Columbia.

Mr. R. G. McConnell—Pyrargyrite, bornite, and argentiferous sphalerite from Alice arm, Observatory inlet; pyrargyrite, bornite, and allophane from the Iliances river; ilvaite from the canyon of Bear river; cimolite from the south fork of Glacier creek, Portland canal, British Columbia.

Mr. A. T. McKinnon—Quartz crystals from Egan; rutile from Templeton; phlogopite from Templeton; vesuvianite from Templeton; garnet from Wakefield; tourmaline from Hull; spinel from Bouchette—all in Ottawa county, Quebec. Magnesite from Grenville, Argenteuil county, Quebec; microcline from Godfrey, Sudbury district, Ontario; limonite from the Helen mine, Michipocoten, Thunder Bay district, Ontario; chalcopyrite from Cobden, Algoma district, Ontario; sodalite in nepheline-syenite, Dungannon, fluorite from Huntingdon, Hastings county, Ontario; three amethyst geodes from Cape Blomidon, Nova Scotia; a series of specimens of gypsum from Hillsborough, Albert county, New Brunswick.

Mr. M. Y. Williams—Columnar grey calcite from Kettle point, Lambton county, Ontario.

Purchased.

Mossy silver from Coniagas mine, Cobalt, Ontario.

The following additions have been made to the foreign section of the mineral collections:—

Presented.

Mr. J. Keele—Residual clay from Augusta county, Virginia, U.S.A.

Mr. E. Stripp, Toronto, Ontario—Model of the Cullinan diamond.

Exchanged.

American Museum of Natural History, New York—Specimen of fibrous talc from Gouverneur, New York.

Geological Survey of India.—Corundum from Paladok, Dharampuri Takuk, Salem district; columbite from the Panama mine, Nawadih; braunite and blaudfordite from Kacharwahi; vredenburgite from Beldongri; spessartite from Mansar; manganese ore from Kandri; spessartite-rhodonite rock from Satak; pyrolusite from Pali, Nagpur district; sitaparite, braunite, arsenite, fermorite, and hollandite from Sitapar—Chlindwara district; samarskite from the

Sankara mine, Gredalur—Neddore district; wolframite from the Sanchi stream—Tavoy district, Burma; kodurite from the Kotakarra mine; mangan-fluor-apatite with spandite from the Kodur mine, Chipurupalle Taluk—Vizagapatam district; hollandite from Balaghat—Balaghat district; spinel in limestone from the Sagyin hills—Mandalay district, Burma; charnockite leptynite, etc., from St. Thomas hill—Madras; corundum in cyanite from Balarampur—Manbhurn. district; charnockite from Arthur's Seat, Yercand, Shevary hills; wimchite Kajlidougri—Jhabua State; orpiment and chrome iron are from unnamed localities.

Purchased.

Carbon from Bahia, Brazil; diamond in conglomerate from Minas Gaeres, Brazil; seventeen diamonds from British New Guinea; thirteen diamonds from Australia; two radiated bortz from the Premier mine; diamond in blue ground; diamond encloser; six diamonds—from South Africa.

BOREHOLE RECORDS. (WATER, OIL, ETC.)

(*E. D. Ingall.*)

During the year 1912, the work of collecting information relating to boring operations throughout Canada has been prosecuted along the lines adopted in previous years.

Thanks to the efforts of Messrs. Dowling, Clapp, and other members of the field staff, samples of drillings and other data were sent in from some important deep bores in the west. On the other hand, owing to the lack of a general response on the part of operators to requests for their co-operation, much valuable geological information is being lost that could be rendered of the greatest possible use in future boring operations. The operators and contracting drillers are beginning, however, to recognize the eventual value to them of a Government office where boring records can be placed on file for future reference and where the data from a number of bores in any district may be compiled and interpreted so as to give light on the economic-geologic problems of great future value to themselves.

Since the inception of the movement for collecting these records the drillings received have been mostly from holes bored with the rope drill. The samples of drillings from the different strata passed through being thus in most cases pulverized material the difficulty of recognizing the formations is greatly enhanced. It was fortunate, therefore, that it was found possible to obtain cores from a diamond drill hole put down at Taber in southern Alberta. This boring is located, according to the published geological maps, at a point where the Belly River beds constitute the surface formation and the hole was already down 1,450 feet when Mr. Dowling visited the spot and was able to induce the operators to send cores to this office. As the cores from the upper part of the well had not been systematically kept, the record of the upper beds was unfortunately lost. Samples from the underlying Benton are, however, available. These not only illustrate the lithological characters of the beds but also contain many well-preserved fossils which enable an opinion to be formed as to their age and position in the geological column.

Some of these fossils occurring at 1,460 feet were determined through the palæontological division to indicate beds towards the top of the Benton. At the lowest point from which cores were received, viz., 2,330 feet and for a short distance above this, the hole would seem to have begun to penetrate the Dakota sandstones, judging from the lithological characters presented.

Samples are being received from a boring at Canora, Saskatchewan. This hole is still in progress and is being put down by the ordinary rope drilling method.

The branch has also been in touch with the further work done by the Maritime Oilfield Co. in the gas and oil fields near Moncton, New Brunswick, from whom a numbers of logs, together with sets of drillings, have been received.

Through the kindness of Senator Poirier a complete set of drillings was received from a test boring made upon Manitoulin island. Amongst other records one set of samples received from Mr. Leo A. Wilson from a hole in Essex county, Ontario, showed a point of considerable interest in the occurrence at a depth of 305 feet of stratum of what appears, under the microscope, to be a bed of aeolian sand similar to that described by Messrs. Scherzer and Grabau as occurring in Monroe county, Michigan, and called by them the Sylvania sandstone. Should further study of these and other drillings give evidence corroborative of this correlation the occurrence of these beds in the region east of their outcrop as

worked out by the above-mentioned investigators, should have an important bearing on the interpretation of the attitude of the strata.

The co-operation with the officials of the Canadian Standard Oil Company mentioned in last year's report was continued. The company decided to make one more effort to locate possible oil or gas pools in the district east of Ottawa and a hole was put down near Russell to strike the Trenton limestone which was penetrated for a short distance. A partial set of drillings was received from this point.

Valuable records and sets of drillings were received from other points in Canada.

The usual inquiries were received and answered during the year pertaining to the geological conditions in various parts of the country in view of proposed boring operations.

In continuation of the field work carried on last year frequent visits were paid during the summer to a number of points in Ottawa and Hull and vicinity, where owing to extensive excavations in progress the rock formations were being bared, and it was thought advisable to make observations previous to filling in.

Some days were also spent in the district accompanying the palæontologists Messrs. Foerste, Twenhofel, and Kindle, in order to facilitate their arrival at points where the desired studies of the formations might be made, as well as to obtain through their observations information which might be useful in the interpretation of the boring records.

Whilst the value to all concerned of systematically collecting bore-hole records and recording and interpreting the data must be evident, the work of impressing the operators with the fact is necessarily a slow process and the success of the work will depend upon the extent to which their interest can be enlisted. The need and value of the data resulting from the successful and extended collection of boring records, is well recognized in the profession and frequently finds expression in technical literature. A number of the considerations involved are well put by J. E. Dick, E.M., of Akron, Ohio, in a paper on 'The Churn Drill Exploration of Placers,' where it is pointed out that 'the object of recording is to keep a section of each hole so that later when the series of holes is completed the strata ......of each hole may be correlated with the strata of other holes. Things that may not appear of importance in the record of any individual hole, may, when read from the accumulated records of all the holes, have considerable bearing.'

This involves a point frequently misunderstood by drillers, viz., the need of sending in complete sets of samples taken as requested at short intervals in their passage through the formations so that, through their examination, facts may be brought out which are essential to the geological interpretation sought, though not of apparent interest to the driller as bearing upon his rate of progress through the rocks.

TOPOGRAPHICAL DIVISION.

(*W. H. Boyd.*)

Part I.

Introduction.

The work of the Division consists in making topographical maps showing the culture (works of man), drainage, and relief of certain tracts of the country. The maps are drawn and printed in three colours—black for culture, blue for all drainage and water areas, and brown for the relief, which is shown by continuous contour lines, these contours serving to picture the land forms and giving the elevations over every part of the map. The field work of the Division consists in making the necessary numerous surveys and measurements, the sketching of the land forms, or the taking of photographs, etc. The material thus obtained is either assembled or compiled in the office during the winter months and the resulting maps are 'finished' and otherwise made ready for reproduction.

The Division has adopted three main distinct methods which are used in the making of a topographical map; these are, the photographic method, the plane-table intersection method, and the plane-table traverse method. Each of these may be used separately or the whole three may be combined in one map area, the method, or combination of methods used, depending on the character of the country. A careful triangulation is made of each area to be mapped; the positions thus established being used to control all the remainder of the work connected with the mapping. In this way and by using the methods stated above, a reliable map is produced, which can be used for a variety of purposes, for example, by engineers to obviate the necessity of making preliminary surveys for the location of railways.

The Division from the time of its organization in 1909 to the beginning of next field season (1913) will have made twenty-five such maps: of these quite a few remain to be published.

The field work during the past season was greatly retarded by bad weather conditions; on account of this the Windermere and Lillooet areas will require more field work before the maps can be completed. The allotment of the field work was as follows: Mr. W. E. Lawson, the Lillooet map-area, B. C.; Mr. K. G. Chipman, the Windermere map-area, B. C.; Mr. A. C. T. Sheppard, the St. John sheet, N. B.; Mr. S. C. McLean, the St. John, N.B., triangulation, the completion of the Columbia-Kootenay, B. C., triangulation, and the Flathead, Alta., triangulation; Mr. B. R. MacKay, the completion of the Blairmore map-area, Alta.; and Mr. D. A. Nichols, the detail mapping of parts of Texada island, B. C. The reports covering the above work are submitted separately, also a report on the levelling done in the vicinity of St. John, N. B.

The writer's time was spent in visiting the different parties in the field and supervising their work in general.

Lillooet Map-Area, British Columbia.

(*W. E. Lawson.*)

Work on a topographic map of a portion of the Bridge River country, Lillooet district, British Columbia, was started early in May of the past season.

The area being mapped lies between longitude 122° 25′ and 123° 00′ west, and latitude 50° 42½′ and 51° 7½′ north, embracing approximately 575 square miles. This area includes the main valley of Bridge river from Cedar creek, west to a point well above the falls; several miles of the South Fork valley; the Cadwallader Creek mining section, part of the Tyaughton Creek basin, and a small area, lying north and east of Shulops ridge, draining into the North Fork.

Photo-topographic methods were used, the triangulation control being worked up from a base line measured on the ranch of W. W. Jones, Bridge river. The main valley roads and the more important trails were traversed with plane-table and stadia, while as many as possible of the old hunting and Indian trails were traversed with plane-table, tape, and aneroid, or compass, pace, and aneroid. Field work and compilations are on a scale of $\frac{1}{96000}$, the scale of publication to be $\frac{1}{125000}$, or approximately 2 miles to 1 inch. Elevations are based on the Canadian Pacific Railway Company's figures for the height of Seton lake above mean sea-level, the accuracy of which has been checked by the Pacific and Great Eastern Railway Company at present doing construction work in the district. A contour interval of 200 feet was adopted.

An unusually wet season, together with unfavourable atmospheric conditions, rendered the completion of the work impossible this year—snow storms bringing the field season to a close early in October.

Mr. N. A. Thompson was attached to the party as topographic assistant, and the following as field assistants: J. Messervey, H. L. Scott, and W. Code.

Windermere Map-Area.

(*K. G. Chipman.*)

The field season of 1912 was spent on the Windermere Map-area. This district, scenically one of the most beautiful in Canada, is each year receiving more attention from mountaineer and tourist, and, with the completion of the automobile road now under construction across the main range of the Rockies from Banff to Windermere, will be one of our most attractive mountain resorts; the increased transportation facilities afforded by the Kootenay Central railway, also under construction, is likely to give impetus to the development of its mines and prospects.

The map-area lies between latitudes 50° 18½′ and 50° 36¼′ north, and longitudes 115° 55¾′ and 116° 37′ west. It contains about 740 square miles and includes the valley of the Columbia river from the mouth of No. 2 creek to the lower end of Columbia lake, also parts of the valleys of Dutch and No. 2 creeks, part of the Stanford range of the Rockies, and that portion of the Purcell range of the Selkirks drained by Toby and Horsethief creeks. The towns of Wilmer, Athalmer, Invermere, and Windermere are also included. Topographically the country varies from the open bench lands of the Columbia River valley, to the rugged alpine Purcell range with Mt. Farnham, 11,342 feet, as the highest point.

The mapping was done on a scale of $\frac{1}{96000}$ with a contour interval of 200 feet after the following general plan. The Columbia-Kootenay triangulation executed by S. C. McLean in 1911 and 1912 furnished the primary control for the map area; in the mountain section this was supplemented by a secondary scheme carried on in conjunction with the camera work; for the valley section a secondary

triangulation control was executed by the writer from a base line established by the main triangulation; for this work a 4-inch Berger transit reading to one minute was used and angles were read by repetition, 3 direct and 3 reverse. The Columbia river, the larger creeks, all roads, and the more important trails in the mountains were put in by plane-table and stadia traverse; the minor trails, details of basins, etc., by telemeter or pace traverse. The details were filled in as follows: in the valleys by plane-table traverse, on the lower slopes of the mountains by plane-table sketching, or by photo-topography, and in the mountains by photo-topography. Elevations are based on the levels of the Kootenay Central railway, the datum adopted being their bench mark at Athalmer, elevation 2574·5 feet; this datum was carried to the mountains by the vertical angles of the secondary and primary triangulation control.

Field work was started on June 10 and continued until October 18. During July, August, and part of September, the work was concentrated in the mountain areas, A. G. Haultain being in charge of a second party most of this time. The work was very much delayed by fogs, rain, and some smoke, owing to which the field work of only about one-half the sheet was completed. Twenty-six camera stations were occupied and approximately 450 miles of traverse run.

Efficient service was rendered by the following: Messrs. A. G. Haultain, S. D. Robinson, L. E. Wright, J. R. Cox, topographical assistants; and Messrs. C. A. Fox, A. M. James, A. F. Barlow, B. N. Simpson, and R. C. McDonald, student assistants.

St. John Map Sheet, New Brunswick.

(*A. C. T. Sheppard.*)

The St. John map-area is a regular fifteen minute quadrangle, bounded by latitudes 45° 10′ and 45° 25′, and by longitudes 65° 55′ and 66° 10′. It embraces the city of St. John, the villages of Fairville, Beaconsfield, Rothesay, and Lorneville, and about fifteen smaller settlements, and has an area of approximately 211 square miles. The field scale for this work was $\frac{1}{48000}$, the publication scale to be $\frac{1}{62500}$, or nearly 1 mile to the inch. On account of the low relief, a contour interval of 20 feet was used, being the most suitable for expressing the topographic features.

Primary control was obtained from a triangulation by Mr. S. C. McLean; from these triangulation stations many points were cut in, also a number of three point locations were made to serve as secondary or traverse control. All the stations were so placed as to be available for use as tie points for traverses. The triangulation was connected to the astronomic pier placed by the Geodetic Survey in 1908, near the Union station in St. John.

Vertical control was obtained from two lines of levels of 15·11 and 6·71 miles in length respectively. The elevations determined by these lines of levels were based on bench marks of the Geodetic Survey along the Intercolonial and the Canadian Pacific railways, and from the tide tables of the Department of Naval Service. The first of these two lines of levels mentioned above was run as primary control levels, and was started from Geodetic Survey, Canada, bench mark 104B at Rothesay, and was connected to Geodetic Survey, Canada, bench mark No. 97B at St. John. Standard Geological Survey bench marks were sunk into rock at important places, and the corrected elevations to the nearest foot, stamped on them.

The party was divided into two camps. The work in the north half of the sheet was placed under the charge of Mr. F. S. Falconer, the writer taking charge of the work in the south half of the sheet. The whole area was mapped by the plane-table traverse method. All roads, railways, shore-lines, the larger creeks,

and those trails suitable for this style of traverse, were run by plane-table and stadia. The balance of the country was covered by a network of stadia and tape traverses. The plane-table and tape method was used in areas that were thickly covered with bush. All tape traverses were connected to the main stadia lines, and the latter to the triangulation, or the secondary points.

The season was rainy, and the heavy fogs proved a serious hindrance to the work. Mr. F. S. Falconer was attached to the party as topographical assistant, greatly aiding the progress of the work. The following men composed the staff of field assistants: Messrs. F. H. McCullough, M. O'Brien, L. A. Badgley, L. Sewell, C. P. Ilsley, J. E. Forbes, J. P. Norrie, F. S. Jones. These men performed their duties in a satisfactory manner.

I wish to express my thanks to the following gentlemen for their kind assistance: Dr. W. Bell Dawson, superintendent of the Tidal Surveys, for information respecting tide levels at St. John; to Prof. D. L. Hutchinson, of the Meteorological Service, for many kindnesses; to Mr. Wm. Murdoch, city engineer of St. John, for city plans, etc.; to Mr. T. C. Burpee, engineer of maintenance of the Intercolonial railway, and to Mr. G. L. Whetmore, division engineer of the Canadian Pacific railway, for blue prints of the railway yards at St. John.

Field work was completed on October 30.

Triangulation Work.

(*S. C. McLean.*)

Field work for the present season covered a local triangulation at St. John, N.B., and secondary chains of triangulation in the Windermere district, B. C., and on the east slope of the Rocky mountains south of Crowsnest pass. Mr. John Lanning rendered efficient assistance throughout the field season.

Instruments and Methods.—For the secondary triangulation a 6¼ inch Berger theodolite with horizontal circle graduated to 10 seconds, vertical circle to 30 seconds, was used. The horizontal angles were read by repetition 6 direct and 6 reverse. For the vertical control, double zenith distances were used with satisfactory results. The centre of all stations was marked by a Canadian Geological Survey standard brass plate bench mark cemented in a drill hole in the rock. The signals were usually cairns of rock. The calculations were adjusted by least squares.

For the local triangulation at St. John the same instrument was used, but only 3 repetitions direct and 3 reverse of the horizontal angles were taken. A vertical control of double zenith distances was attempted but proved unsatisfactory, a result to be expected in this type of country. Signals were for the most part tripods covered with cotton or flags and the centres were not marked permanently. In the calculations no adjustment was made beyond obtaining sufficient check distances.

St. John Triangulation.

This triangulation was required to furnish only the primary control of the St. John map-area and so was purely local in character.

A base line about 5,000 feet in length was established on the Great Marsh to the north of St. John, and an expansion made therefrom to the necessary control points. Fourteen stations were signalled and observed; besides these, such prominent church steeples, buildings, etc., as promised to help the control, were cut in. The necessary azimuth was obtained by an observation on Polaris from one of the stations. The triangulation was tied to the astronomic pier, established in St. John in 1908 by the Astronomic Branch of the Department of the Interior, by a short primary traverse from the pier to Fort Howe station. Computation of the geodetic positions of the stations was begun and the data necessary for its

completion handed to A. C. T. Sheppard, in charge of the topography, before leaving the field. Field work began on May 6 and finished on June 5. The weather conditions were unfavourable, about twelve days being lost through fog and rain.

Columbia-Kootenay Triangulation.

This scheme of secondary triangulation was planned and started in 1911. During the present field season it was continued only as far as was necessary to make it available for the control of the Windermere topographic sheet. For this purpose three of the stations left from 1911 were observed; also, in conjunction with K. G. Chipman, topographer in charge of the Windermere sheet, the several intermediate stations necessary to give a reduction to a base line for a local valley triangulation were established.

Field work began on June 12 and finished July 17. Weather conditions were very unfavourable, about 15 days being lost from this cause.

Flathead Triangulation.

This secondary triangulation chain is planned to extend north from the International Boundary. Its immediate purpose is the control of the two 30 minute topographic sheets between latitude 49° 00′ and 49° 30′ N. and longitude 114° 00′ and 115° 00′ W. Owing to the late date at which this work was started, due to delays in other parts of the field, only the eastern sheet was fully controlled. Kishinena—North Divide, stations of the International Boundary triangulation, was used as base, and the triangulation was carried north along the east slope of the Rocky mountains to Blairmore where it was connected with, and furnishes correct initial positions for, the local triangulation executed in 1911 by W. H. Boyd for the control of the Blairmore sheet. In all, eleven stations were signalled, nine of which were observed. Besides these stations many of the prominent mountain peaks together with points at Pincher Station and Pincher Creek were cut in. Field work here began July 22 and ended October 14. The wet season delayed work considerably, but we were here able to use much of the unfavourable weather for travelling, so the delays were not so serious as in the earlier part of the season.

Blairmore Map-Area, Alberta.

(B. R. Mackay.)

The field season of 1912 was spent in completing the mapping of the Blairmore map-area begun in 1911. Field work on this area was started May 16 and continued until November 9.

The method employed was essentially plane-table survey. Due to the exceptionally wet season and heavy winds the party was greatly hampered in the work, and much of the area favourable for plane-table intersection had to be mapped by plane-table traverse.

The area mapped was 150 square miles. The field scale used was 4,000 feet to 1 inch with a contour interval of 100 feet. The publication scale will be $\frac{1}{62500}$ or approximately 1 mile to 1 inch.

Among the topographic features of interest shown on the sheet are the following: the Frank landslide; block mountains; glacial sculpture in the Livingstone range expressed in cirques, U-shaped valleys, lateral moraines, truncated spurs, etc.; drainage controlled by faulting, and river terraces which have been shown by hachures.

Messrs. C. P. Sills, C. B. Bate, J. A. Tilston, P. G. B. Gilbert, and D. S. Halford were attached to the party as field assistants and rendered efficient service. Towards the close of the field season the party was increased by the addition of J. R. Cox, N. B. Simpson, and J. Lanning, and later by D. A. Nichols with two assistants, E. E. Freeland and B. W. W. McDougall, all of whom assisted greatly in the completion of the work.

Texada Island Map-Area, British Columbia.

(*D. A. Nichols.*)

The instructions for the field season of 1912 called for the detailed mapping of the iron area adjacent to the Prescott, Paxton, and Lake mines on the south side of Texada island, also of a belt along the north coast of the island to include the principal mining areas in that vicinity.

The detail map-area, comprising approximately 1·2 square miles, is situated on the southern slopes of the ridge which parallels the coast on the south side of the island. The scale adopted in mapping was 400 feet to 1 inch, with a contour interval of 20 feet. The methods employed were transit-stadia control, run with closed traverses, and plane-table-stadia traverses for filling in detail.

The number of transit control stations was 198; the plane-table stations, 721, and the total number of sights taken was 12,300. This gives 65 sights per square inch of map surface, which ensures absolute control of all topographic features.

The compilation was done in the field, and the manuscript brought to the office ready for inking and lettering. The field work for this sheet was completed on August 10.

After the completion of the above area, work on the map of the north end of the island was commenced.

This map covers approximately 8 square miles. It includes the properties of the mines that are at present being worked, viz: the Marble Bay, the Little Billy, and the Cornell, also those of the Copper Queen, the Loyal, and several others not at present being worked. There are two villages on the sheet, Van Anda and Blubber Bay.

The scale adopted in mapping this area was 2,000 feet to 1 inch, with a contour interval of 50 feet. The control was run with transit and stadia in the same manner as on the 400-foot scale. The detail was filled in by means of plane-table and stadia, plane-table, tape, and barometer, and Batson sketching case, tape, and barometer. The stadia methods were used along roads, the shore-line, and in all open country. On the major portion of the country covered by the north part of the sheet, however, the underbrush was so uniformly dense, that only the Batson sketching case and tape traverse could be run. These traverses were placed sufficiently close together to ensure control of all features.

On both the detail map of the iron area, and the general map-area, the magnetic declination was so variable that the compass could not be relied upon for traverse work, so that orienting by backsight had to be adopted.

Much wet weather, during June and July, considerably lessened the speed with which the work could be accomplished.

Field work was completed on October 9, after which date, acting under instructions from Mr. W. H. Boyd, I proceeded with two assistants to Blairmore, Alberta, to assist Mr. B. R. MacKay in the completion of the work in that vicinity.

Mr. E. E. Freeland, as topographical assistant, rendered extremely efficient service throughout the season. The field assistants were B. W. W. McDougal, M. B. Heebner, R. H. Rice, J. Ross, W. E. Cockfield, and W. A. Delahey.

Part II.

Spirit Levelling, St. John Sheet, New Brunswick.

Levels were run from Rothesay, N. B., via the new road from Rothesay to Golden Grove, the Golden Grove, Churchland, Upper Loch Lomond, Westmorland and Marsh roads, Gilbert Lane, and the Intercolonial railway, to the railway station at St. John, N. B. The instrument work was done by F. S. Falconer.

Instruments and Methods.—A 15-inch Y-level and New York target rod were used. The line was run only once. Sights were limited to 300 feet and backsights and foresights, taken on a steel pin, were of equal length or were equalized daily. While running the line, temporary bench marks were established about every mile, later permanent standard brass plate bench marks were placed at important points. The standard brass plate bench mark is a heavy brass plate about 3½ inches in diameter; on the under side is a fluted brass bolt about 3 inches long, a hole is drilled in solid ledge or a large boulder and the bench mark cemented therein. It bears the inscription 'Geological Survey of Canada, Elevation,' with the elevation stamped to the nearest foot. For temporary bench marks the centre of a cross chiselled on rock, or a small brass nail and washer in a tree stump or root were used.

Datum.—Mean sea-level, as carried from Calais, Maine, to St. John, N. B., by the precise levels of the Geodetic Survey of Canada. The Geological Survey levels were run between bench marks 104B and 97B of the above precise levels with the following results:—

	Elevation in feet.
B.M. 104B. —Rothesay—Geodetic Survey (datum for this line)	16·97
B.M. 97B. —St. John—Geodetic Survey	21·78
B.M. 97B. —St. John, as per Geological Survey line	21·62
Closing error Geological Survey line	0·16

The above figures and those in the following list of bench marks are actual readings without adjustment. Distances are from stadia readings along route of levels.

Descriptions and Elevations of Bench Marks, from I. R. C. Station, Rothesay, to I. R. C. Station, St. John.

	Elevation in feet.
Rothesay —On Intercolonial railway, about 525 feet north of mile-post 9 from St. John, in rock ledge on east side of road from railway station to wharf; opposite small boat-house. Geodetic Survey of Canada brass bolt B.M. 104B. datum	16·97
Rothesay —0·4 miles from—Intersection of Golden Grove and Hampton roads	54
Rothesay —1·4 miles from—Pugsley's dam—Water level, May 20, 1913	150
Rothesay —1·5 miles from—100 feet north of small creek from dam—on west side of road directly opposite Carpenter's barn—Cross on granite boulder on edge of road	148·93
Rothesay —2·6 miles from—0·6 miles northwest of Golden Grove post-office. Cross on rock ledge 5 feet west of road	175·05
Rothesay —3·2 miles from—50 feet west of the junction of the new road from Rothesay to Golden Grove and the main Golden Grove road, on a large angular boulder in corner of small field—Standard brass plate B.M.	191·76

	Elevation in feet.
Rothesay —3·3 miles from—Dolan lake—Water level, May 21, 1912	179
Rothesay —3·6 miles from—Willis' mill pond—Water level May 21, 1912	222
Rothesay —4·1 miles from—0·3 miles east of junction of Golden Grove and Churchland roads—Cross on large boulder on southwest edge of road	278·42
Rothesay —4·5 miles from—Adam lake—Water level May 22, 1912	332
Rothesay —5·1 miles from—0·2 miles southeast of junction of Scottand Churchland roads, on a small hill crest—Brass nail and washer on a knob cut in birch stump on the west side of the road	362·42
Rothesay —5·2 miles from—McCormac lake—Water level, May 22, 1912	334
Rothesay —6·1 miles from—0·4 miles northwest of junction of Frog pond and Churchland roads—Cross on large blue boulder on west side of road	353·49
Rothesay —6·7 miles from—within the sharp angle formed by the junction of the Churchland and Loch Lomond roads, on a large flat boulder—Standard brass plate B.M.	325·21
Rothesay —7·6 miles from—junction new pipe line road and Loch Lomond road	278
Rothesay —7·8 miles from—1·1 miles south of junction of Churchland and Loch Lomond roads; 400 feet southwest of Desmond's house; 80 feet northeast of small stream—Cross on boulder partly buried on north side of road	258·36
Rothesay —8·7 miles from—0·5 miles northeast of Applegates' store, Lakewood; 300 feet southwest of a red house—Cross on boulder in south ditch of road.	233·91
Rothesay —9·7 miles from—0·5 miles southwest of Applegate's store, Lakewood; 300 feet northeast of small lake on north side of road—Brass nail and washer on knob cut in small hemlock stump, 18 inches high and 1 foot from west road fence	193·56
Rothesay —9·8 miles from—St. John Reservoir—Water level, May 25, 1912	177
Rothesay —10·9 miles from — 0·25 miles northeast of junction of Hickey and Loch Lomond roads, in a conglomerate boulder on south side of road—Standard brass plate B.M.	160·57
Rothesay —11·2 miles from—Junction of Loch Lomond and Hickey roads	170
Rothesay —11·7 miles from—Junction Loch Lomond and Silver Falls roads	119
Rothesay —12·2 miles from—2·9 miles from I.R.C. station, St. John; 700 feet south of entrance to Catholic home—Cross on boulder on west side of road, behind telegraph post	121·03
St. John — 2 miles from I.R.C. station—0·4 miles east of intersection of Westmorland and Courtenay Bay roads; about 450 feet southeast of old chimney in field; 30 feet west of a lane, on rock ledge on south side of road—Cross about 7 feet above road level	86·44
St. John — 1·5 miles from I.R.C. station. Intersection of Courtenay Bay and Westmorland roads	26
St. John — 1·2 miles from I.R.C. station. Intersection of Westmorland and Marsh roads	15
St. John — I.R.C. Station—in foundation stone of south wall, 6 inches from southwest corner of main building and immediately to rear of facade—Brass bolt B.M. 97B. set by Geodetic Survey of Canada	21·62
Elevation according to Geodetic Survey precise levels	21·78

Part III.

Flathead Triangulation, British Columbia and Alberta. Geographic Positions and Descriptions of Stations.

(*S. C. McLean.*)

The positions of the stations of the Flathead triangulation depend upon the positions of stations North Divide and Kishinena as determined by the International Boundary Survey. All primary stations are computed from closed and adjusted triangles, the unoccupied stations from two or more unclosed triangles. The elevations depend on the levels of the Crowsnest branch of the Canadian Pacific railway and are the mean of three or more values without adjustment.

Names are for the purpose of distinguishing the signals and are not necessarily geographic names for the features. "C. G. S." stands for "Canadian Geological Survey."

KISHINENA (B.C.)

International Boundary Survey, 1903. C. G. S., 1912.

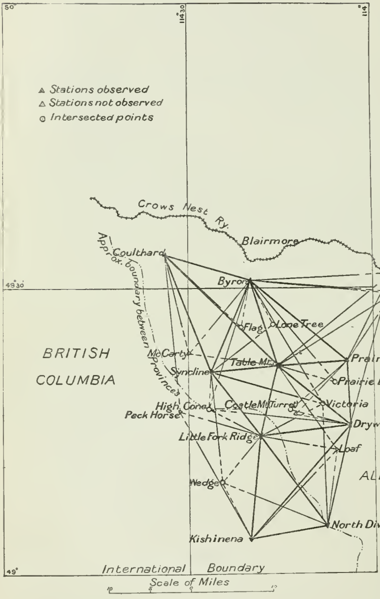
This station is on a high rocky mountain about 8 miles east of the Flathead river and just north of Kishinena creek, the first high peak when entering the mountains from the west; about 2½ miles northeast is a second and higher bluffy peak. To reach, take the Alberta trail and camp on the meadows at the foot of the southwest slope of the mountain, near where the old trail (not the present so-called wagon road) crosses to the south side of the creek for a short distance. The station is reached from this point by an easy climb of 4,200 feet up the southwest slope of the mountain.

Station Mark.—The mountain top is of a soft shale and weathers readily, the old centre had disappeared and was located as nearly as possible from sundry chisel marks and the remains of the old cairn. A ¾-inch steel drill about 9 inches long was driven firmly into the shale and left for a new centre.

Signal.—A rock cairn about 3 feet high with centre pole and target facing northwest, on centre.

Latitude, 49° 03′ 42″·04. Longitude, 114° 20′ 10″·35 (Boundary Survey).
Elevation, 8497 feet.

To Station.	Azimuth	Back Azmiuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Little Fork	186 02 58·3	6 04 17·2	4·301638
Drywood	221 40 41·0	41 52 57·9	4·471611
North Divide (Boundary 1903)	260 53 06·4	81 02 23·6	4·180606
Kintla (Boundary 1903)	331 03 33·9	151 07 58·3	4·168246



FLATHEAD TRIANGULATION, 1912.
BRITISH COLUMBIA & ALBERTA

Fig. 11.

NORTH DIVIDE (B.C.—ALTA.)

International Boundary Survey 1903. C. G. S. 1912.

Station is on a high bare hill sloping gradually to westward and abruptly to eastward, distinguished by a red cap overlying a grey ridge. To reach station take the Alberta trail from the Flathead river to Alberta via Kishinena creek and the townsite of Oil City; camp on the trail at foot of bare grassy side hill about 1 mile east of camp of Royal Canadian Oil Company (first bare slope west of, and about 5 miles from, summit of Rockies). Station is about due north of camp; climb ridge and follow around to main divide where station will be found on the highest point. Station cannot be seen from camp, from the top of the first ridge or from any point on the trail east of the junction of Kishinena and Akamina creeks—3 hours hard work from camp.

Station Mark.—A drill hole in a small boulder.
Signal.—Cairn of rock 3½ feet high and small tripod on centre.
Latitude 49° 04′ 59″·11. Longitude 114° 07′ 52″·86 (Boundary).
Elevation, 8,267 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Kishinena	81 02 23·6	260 53 06·4	4·180606
Little Fork	143 52 47·3	323 44 48·3	4·336986
Drywood	193 38 41·4	13 41 40·4	4·307128

WEDGE (B.C.) (*Not Occupied*).

C. G. S. 1912.

This is the highest point of a mountain lying on the extreme west slope of the Rockies about half-way between Packhorse and Kishinena and standing out well into the valley of the Flathead river; its top is a short grassy east and west ridge with no decided summit.

Station Mark.—Highest point.
Latitude, 49° 09′ 32″·2. Longitude, 114° 24′ 50″·9.
Elevation, 8,366 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Syncline	175 29 47	355 28 43	4·33556
Little Fork	220 32 17	40 37 09	4·07846
North Divide	292 07 26	112 20 16	4·34832
Kishinena	332 13 51	152 17 23	4·08717

LOAF (ALTA.) (*Not Occupied.*)

C. G. S. 1912.

On the summit of a high dome mountain about 8 miles southeast of Castle mountain. This mountain is on the east side of the valley of the south branch of the Little South Fork of Oldman river and can be reached either from this valley or from the south fork of Drywood creek.

Station Mark.—A 6-foot cairn (no centre).
Latitude, 49° 13′ 03″·0. Longitude, 114° 06′ 08″·4.
Elevation, 8,635 feet.

To Station.	Azimuth			Back Azimuth			Log. Distance.
	°	′	″	°	′	″	Metres.
North Divide	8	04	08	188	02	50	4·17893
Kishinena	44	38	50	224	28	13	4·38601
Little Fork	99	54	15	279	44	57	4·18029
Table Mountain	144	59	47	324	52	41	4·29567

LITTLE FORK (ALTA.)

C. G. S. 1912.

About 24 miles southwest of Pincher Creek, on a high bare ridge on the west side of south branch of Little South Fork of Oldman river. This ridge is directly across the valley from, and a little south of, Castle mountain, runs approximately north and south for about one-half mile or more, has three or four cirques on its eastern slope, and a number of rounded summits; the station is on the most southern and highest summit. To reach this station take the trail up the above-mentioned south branch of Little South Fork.

Station Mark.—C. G. S. brass plate bench mark cemented in drill hole in solid rock and surrounded by cairn 6 feet high.
Latitude, 49° 14′ 26″·73. Longitude, 114° 28′ 26″·0.
Elevation, 8,261 feet.

To Station.	Azimuth.			Back Azimuth.			Log. Distance.
	°	′	″	°	′	″	Metres.
Kishinena	6	04	17·2	186	02	58·3	4·301638
Syncline	142	50	51·6	322	44	56·0	4·195334
Table Mountain	194	38	46·5	14	41	00·0	4·147441
Drywood	262	51	58·3	83	02	57·2	4·248565
North Divide	323	44	48·3	143	52	47·3	4·336986

DRYWOOD (ALTA.)

C. G. S. 1912.

About 17 miles south of Pincher Creek, on a high limestone peak on eastern edge of the range. This peak lies between the North and South forks of Drywood creek and can be reached and climbed from either fork; trails and good feed in both forks; an easy climb of about 3 hours from camp.

Station Mark.—C. G. S. brass plate bench mark cemented in 100 pound boulder on highest point of mountain, surrounded by rock cairn 6 feet high.

Latitude, 49° 15′ 37″·07. Longitude, 114° 03′ 56″·23.

Elevation, 8,102 feet.

To Station.	Azimuth.			Back Azimuth.			Log. Distance.
	°	′	″	°	′	″	Metres.
North Divide	13	41	40·4	193	38	41·4	4·307128
Kishinena	41	52	57·9	221	40	41·0	4·471611
Little Fork	83	02	57·2	262	51	58·3	4·248565
Table Mountain	129	13	44·4	309	04	58·3	4·257031
Byron	145	35	43·8	325	23	35·9	4·533374
Prairie Ridge	178	20	00·3	358	19	46·6	4·095272

CASTLE MOUNTAIN (TURRET) (ALTA.) (*Not Occupied*).

C. G. S. 1912.

A sharp limestone mountain about 20 miles southwest of Pincher Creek and on the east side of the valley of the Little South Fork of Oldman river, its northern and highest summit culminates in a turret which makes it the most distinctive peak in the Rockies between Crowsnest pass and the boundary. To reach, follow trail described under Little Fork until you are under the mountain, then climb western slope.

Station Mark.—Highest point of turret.

Latitude, 49° 17′ 13″·1. Longitude, 114° 13′ 38″·1.

Elevation, 8,382 feet.

To Station.	Azimuth			Back Azimuth			Log. Distance.
	°	′	″	°	′	″	Metres.
Prairie Ridge	230	09	28	50	16	36	4·17081
Drywood	284	05	16	104	12	37	4·08390

CASTLE MOUNTAIN (SIGNAL) (ALTA.) (*Not Occupied*).

C. G. S. 1912.

On the second summit of Castle mountain about 1 mile south of and only a little lower than the turret—a distinct bare triangular peak sloping gradually to the west and abruptly to the east—(see Castle Mountain turret).

Station Mark.—C. G. S. brass plate bench mark cemented in drill hole in rock and surrounded by cairn 6 feet high.

Latitude, 49° 16′ 42″·1. Longitude, 114° 12′ 52″·2.
Elevation, 8,338 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Prairie Ridge	225 00 13	45 06 46	4·16960
Drywood	280 26 44	100 33 30	4·04213

PACK HORSE (B.C.) (*Not Occupied*).

C. G. S. 1912.

The mountain carrying this station is on the west slope of the Rockies about 8 miles south of the North Kootenay pass—it is a comparatively low peak standing well out into the valley of the Flathead river; from the north and south it appears as a fairly sharp cone, from the east and west as a hump on the ridge resembling a pack on a horse's back. To reach, use the trail on the Flathead river, camp at Don Cate's old cabin, and climb from there.

Station Mark.—C. G. S. plate bench mark cemented in drill hole in solid ledge and surrounded by rock cairn 6 feet high.

Latitude, 49° 17′ 03″·8. Longitude, 114° 31′ 26″·5.
Elevation, 7,897 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Drywood	274 25 10	94 46 01	4·524634
Little Fork	287 00 45	107 10 36	4·217764
Kishinena	330 59 19	151 07 51	4·451847

HIGH CONE (ALTA.) (*Not Occupied*).

C. G. S. 1912.

The summit of a high, bare, conical peak on the main divide of the Rocky mountains and at the head-waters of the north branch of Little South Fork of Oldman river; this peak is easily distinguished, being the highest in the vicinity and an almost perfect cone. It is probably most easily reached by the trail up the little South Fork of Oldman river.

Station Mark.—Highest point of peak.
Latitude, 49° 17′ 22″·0. Longitude, 114° 26′ 43″·6.
Elevation, 8,552 feet.

To Station.	Azimuth	Back Azimuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Syncline	184 38 15	4 38 37	3·85105
Byron	198 15 00	18 20 10	4·41868
Drywood	276 32 24	96 49 40	4·44449
Little Fork	298 14 22	118 20 40	4·05789

VICTORIA (ALTA.) (*Not Occupied*).

C. G. S. 1912.

The summit of a high sharp dark limestone peak about 16 miles south of Pincher Creek and 4 miles due east of Castle mountain, the most prominent peak on the extreme eastern slope of the Rockies except down near the boundary line.

Station Mark.—Highest point of peak.
Latitude, 49° 17′ 50″·1. Longitude, 114° 08′ 28″·6.
Elevation, 8,437 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Little Fork	62 34 43	242 27 10	4·13417
Byron	150 07 53	329 59 11	4·443 4
Syncline	106 11 42	285 58 13	4·35048
North Divide	358 16 06	178 16 33	4·37716

PRAIRIE BLUFF (ALTA.) (*Not Occupied*).

C. G. S. 1912.

On the first mountain south of the valley of the South Fork of Oldman river and on extreme eastern edge of the range. This mountain is an east and west ridge with a low summit and abrupt slope on its eastern end; it stands well out into the foothills like a sentinel for the range, is in the northeast corner of township 4, range 1, west 5th, and is easily reached from the open country to the east.

Station Mark.—A low cairn on highest point.
Latitude, 49° 20′ 03″·8. Longitude, 114° 06′ 15″·9.
Elevation, 7,378 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Table Mountain	105 53 09	285 46 08	4·06543
Byron	140 23 49	320 13 27	4·41264

SYNCLINE (ALTA.)

C. G. S. 1912.

About 24 miles west of Pincher Creek on the first high rocky mountain on the north side of the valley of the west branch of Little South Fork of Oldman river; the strata on top form a shallow syncline. A good trail up the Little South Fork joins, near the mountain, a wagon road from Beaver Creek to the oil wells farther up the fork. Camp in the meadows below mountain; climb to top of ridge and follow northwest to station.

Station Mark.—C. G. S. brass plate bench mark cemented in drill hole in solid ledge on highest point, and surrounded by a 6 foot cairn.
Latitude, 49° 21′ 11″·00. Longitude, 114° 26′ 15″·20.
Elevation, 7,991 feet.

To Station.	Azimuth	Back Azimuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Coulthard	158 16 06·1	338 10 21·9	4·390696
Byron	203 11 40·7	23 16 29·2	4·287771
Table Mountain	265 07 13·0	85 15 22·5	4·116128
Little Fork	322 44 55·9	142 50 51·6	4·195334

TABLE MOUNTAIN (ALTA.)

C. G. S. 1912.

About 17 miles southwest of Pincher Creek on the first mountain south of the main valley of the South Fork of the Oldman river and on the extreme eastern edge of the range. It stands out prominently in the valley, is bluff to the north and east, and its top is a comparatively flat ridge or series of ridges. It can be easily reached by trail either up Gladstone creek, Beaver creek, or the South Fork of Oldman river.

Station Mark.—C. G. S. standard plate bench mark wedged in drill hole in 100 pound boulder on highest point of mountain, surrounded by a cairn 5½ feet high.

Latitude, 49° 21′ 46″·47. Longitude, 114° 15′ 30″·04.

Elevation, 7,303 feet.

To Station.	Azimuth.			Back Azimuth.			Log. Distance.
	°	′	″	°	′	″	Metres.
Little Fork	14	41	00·0	194	38	46·5	4·147441
Syncline	85	15	22·5	265	07	13·0	4·116128
Coulthard	134	37	17·0	314	23	22·5	4·491464
Byron	162	18	18·5	342	14	56·9	4·244596
Prairie Ridge	265	35	06·9	85	43	39·8	4·135945
Drywood	309	04	58·3	129	13	44·4	4·257031

PRAIRIE RIDGE (ALTA.)

C. G. S. 1912.

In the foot-hills about 10 miles southwest of the town of Pincher Creek, on the summit of one of a series of bare grassy knolls which form a southeast-northwest ridge, 5,000 to 6,000 feet high, just west of Pincher creek; the station is not on the highest knoll but on the first prominent one northwest of it from which the southern summit of Castle mountain can be seen; it is near the eastern line of section 9, township 5, range 1, west 5th; directly below station to the north-east and one-half mile away is a ranch and ranch buildings.

Station Mark—C. G. S. standard brass plate bench mark cemented in a drill hole in a triangular 75 pound boulder buried flush with the ground; a small cairn, with tripod signal over it, surrounds centre.

Witness.—A dwarfed pine, 1 foot in diameter, blazed on four sides, 71 feet west of centre.

Latitude, 49° 22′ 20″·00. Longitude, 114° 04′ 14″·18.

Elevation, 5,588 feet.

To Station.	Azimuth.			Back Azimuth.			Log. Distance.
	°	′	″	°	′	″	Metres.
Table Mountain	85	43	39·8	265	35	06·9	4·135945
Byron	129	42	45·4	309	30	50·3	4·391172
Drywood	358	19	46·6	178	20	00·3	4·095272

McCARTY (ALTA.) (*Not Occupied*).

C. G. S. 1912.

About 25 miles west of Pincher Creek on the summit of a high bare dome mountain at the head of the South Fork of the Oldman river; this mountain stands well out in the valley of the South Fork, is east of the main divide of the Rockies, and south of the creek. To reach, take the wagon road or trail up the South Fork, camp in the last large meadows east of the divide and climb from there; a good 4 hours climb or more.

Station Mark.—C. G. S. brass plate bench mark cemented in drill hole in ledge and surrounded by cairn 6 feet high.
Latitude, 49° 23′ 05″·8. Longitude, 114° 29′ 59″·8.
Elevation, 7,722 feet.

To Station.	Azimuth	Back Azimuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Byron	220 23 14	40 30 53	4·27337
Table Mountain	277 51 23	98 02 24	4·24839

FLAG (ALTA.) (*Not Occupied*).

C. G. S. 1912.

On a bare knoll of the ridge in the angle between the South Fork and Little South Fork of Oldman river—hill is bare on top except for a few stunted trees, slopes gradually to the south and east, and more abruptly to north and west. Station is in northwest corner of section 33, township 5, range 3, west 5th.

Station Mark.—A large tree partially trimmed and with flag pole and flag.
Latitude, 49° 25′ 54″·4. Longitude, 114° 21′ 29″·3.
Elevation, 5,915 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Coulthard	133 30 28	313 21 06	4·31119
Byron	191 45 57	11 47 08	3·96678

LONE TREE (ALTA.) (*Not Occupied*).

C. G. S. 1912.

On highest bare grassy rounded hill of ridge between Little South Fork and Beaver creek. Hill strictly bare except for a lone fir tree on top; it is in the north-east corner of section 36, township 5, range 3, west 5th.

Station Mark.—The lone tree.
Latitude, 49° 26′ 10″·6. Longitude, 114° 16′ 17″·3.
Elevation, 5,922 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Syncline	52 33 00	232 25 26	4·18186
Byron	152 53 24	332 50 38	3·98357

PINCHER CREEK (ELEVATOR) (ALTA.) (*Not Occupied*).

C. G. S. 1912.

The centre of a grey elevator in the town of Pincher Creek, Alta.

Latitude, 49° 29′ 29″·7. Longitude, 113° 56′ 45″·1.

To Station.	Azimuth	Back Azimuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Prairie Ridge	34 19 45	214 14 03	4·20590
Byron	95 05 21	274 47 43	4·44838

PINCHER CREEK (SMOKESTACK) (ALTA.) (*Not Occupied*).

C. G. S. 1912.

The smoke-stack of the electric light plant, town of Pincher Creek, Alta.

Latitude, 49° 29′ 34″·3. Longitude, 113° 56′ 18″·3.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Table Mountain	58 12 41	237 58 06	4·43681
Byron	94 43 00	274 25 02	4·45642

PINCHER STATION (ELEVATOR) (ALTA.) (*Not Occupied*).

C. G. S. 1912.

The centre of a red elevator at Pincher Station on the Crowsnest branch of the Canadian Pacific railway, Alta.

Latitude, 49° 31′ 27″·5. Longitude, 113° 56′ 55″·6.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Drywood	16 09 36	196 04 17	4·48520
Byron	87 37 31	267 20 02	4·44375

BYRON (ALTA.)

C. G. S. 1912.

About 3½ miles south of Passburg, a station on the Crowsnest branch of the Canadian Pacific railway, on a bare grassy conical hill, the highest point of the divide between the east branch of Byron creek and the South Fork of Oldman river. Station is near southwest corner of section 34, township 6, range 3, west 5th, and can be easily reached from the trail on the east branch of Byron creek. Camp somewhere near the divide and follow ridge to highest point.

Station Mark.—C. G. S. standard brass plate bench mark cemented in drill hole in solid rock.

Latitude, 49° 30′ 47″·98. Longitude, 114° 19′ 55″·40.

Elevation, 6,027 feet.

To Station.	Azimuth	Back Azimuth	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Coulthard	106 44 00·0	286 33 26·5	4·242458
Prairie Ridge	309 30 50·3	129 42 45·4	4·391172
Table Mountain	342 14 56·9	162 18 18·5	4·244596

COULTHARD (ALTA.)

C. G. S. 1912.

About 7 miles southwest of Blairmore, a station on the Crowsnest branch of the Canadian Pacific railway, on the high rocky mountain at the head of York creek; the ridge of the mountain forms a crescent concave to the east with the highest point at the southeast end. To reach, follow the trail past the old lumber camp on North fork of York creek as far as possible, climb the ridge to the south and follow it to the station.

Station Mark.—C. G. S. brass plate bench mark cemented in drill hole in solid rock and surrounded by a 6 foot cairn.

Latitude, 49° 33′ 30″·02. Longitude, 114° 33′ 48″·15.

Elevation, 8,665 feet.

To Station.	Azimuth.	Back Azimuth.	Log. Distance.
	° ′ ″	° ′ ″	Metres.
Byron	286 33 26·5	106 44 00·0	4·242458
Table Mountain	314 23 22·5	134 37 17·0	4·491464
Syncline	338 10 21·9	158 16 06·1	4·390696

BIOLOGICAL DIVISION.

BOTANY

(*John Macoun.*)

After the date of my last summary report I completed the determination of the plants I collected in the Ottawa district during the previous summer, writing the localities into the manuscript of the Ottawa Flora which I had written the previous winter, and so completed the enumeration of the Ottawa species with their distribution in the 30-mile zone. This manuscript was typewritten and so made ready for the printer. When this work was completed I worked on our collection of Vancouver Island plants in anticipation of spending the summer there for the purpose of completing the flora of the island. I was taken ill March 6 and was not able to travel until April 24 when I went to Vancouver island, accompanied by my assistant, Mr. J. M. Macoun. Leave of absence was given me until June 1, but before that time I had begun to list and collect the plants in the vicinity of Sidney where I was located, and from that time until the end of the collecting season for flowering plants I was busy every day on the flora of that region, making a very complete collection and adding many species to the known flora of Vancouver island. During the summer British Columbia botanists visited me from time to time bringing their collections with them, and in this way much was added to my knowledge of the flora of Vancouver island. During the last three months my time has been devoted almost exclusively to the collecting of Cryptogams, the autumn and winter season on Vancouver island being the best for that purpose. Large collections of mosses, lichens, hepaticae, fungi, and sea-weeds have been made which I send from time to time through the office to specialists for determination. I am in almost daily communication with my assistants and in that way keep in close touch with the office work.

As usual the routine work of the office was done last winter chiefly by my assistant, Mr. J. M. Macoun, his principal work apart from this being the determination and mounting of specimens collected in early years. Many thousand sheets of these specimens have still to be worked over and mounted. He accompanied me to Vancouver island in April and acted as my assistant until July 24, going much farther afield, however, than I did, including visits to many of the islands in the Gulf of Georgia and up the coast to Nanaimo. On July 24 he went to Strathcona park where he remained until the first week of September. Through the kindness of the Deputy Minister of Public Works and Mr. R. H. Thomson, chief engineer in charge of Strathcona park, he lived at the camps of the parties working under Mr. Thomson, and no charge was made for either transport or maintenance. He reports that there is very little animal life in Strathcona park. No elk or deer were seen either by him or anyone else in the park during the summer and even small mammals and birds were rarely noted. As complete a collection as possible of the plants was made and although the number of species was not so great as might have been expected—only 350 species of flowering plants—twenty-four species new to Vancouver island were found, and six new to science, among the latter, a fern, ***Polystichum andersoni***, Hopkins, the first new species of fern found in Canada in over fifty years.

Both my son and I attended the Forestry Convention at Victoria September 4-6, my son returning to Ottawa a few days afterwards.

As soon as he returned he worked up his own collection of plants and the very fine collection made by Dr. Cairnes in the Yukon district; a short report on this Yukon collection is appended. A larger number of plants than usual have been sent in this autumn and winter for determination and most of these from good botanists, so that a great deal has been added to our knowledge of the Canadian flora in this way. After the determination of the 1912 collection was completed he worked as in other years on the older collections, but parts of two or three days have been devoted each week to the preparation of simple keys for the Ottawa flora in collaboration with Dr. M. O. Malte, Agrostologist of the Central Experimental Farm. These, when finished, will add immensely to the value of the proposed Ottawa Flora, as by their means the plants of the Ottawa region may be determined without the aid of other books.

In anticipation of the transfer of our herbarium to new cases, Miss Stewart, when not otherwise employed, is now engaged in going over the herbarium, replacing the old wrappers by new when necessary and re-writing indistinct or incomplete labels.

Up to December 31, 571 letters were written in connexion with our work, 896 sheets of botanical specimens were purchased, 2,150 mounted, 1,518 distributed to other herbaria, 465 received in exchange, and 463 sheets named for correspondents.

REPORT ON PLANTS COLLECTED BY DR. D. D. CAIRNES ON THE 141ST MERIDIAN IN 1912.

This collection made on the 141st meridian between latitude 65° 11′ N. and 67° 24′ N. includes most of the species found in 1911[1], but in addition many that were not secured that year. A list of the additions is given below with short notes on the more interesting species. Five new species from this region have yet to be described; three collected in 1911 and two in 1912. They are an *Eritrichium*, an *Arnica* and an *Antennaria* from the 1911 collection and a *Campanula* and an *Erigeron* collected in 1912. Further study of the plants collected in 1911 has resulted in the addition of four species not included in the published list, *Carex scopulorum*, new to Canada, *Arenaria arctica*, *Ranunculus nivalis* and *Sieversia glacialis*.

Cyperaceæ.

Eriophorum vaginatum, L.
Lat. 67° 04′ N.

Liliaceæ.

Lloydia serotina (L.) Sweet.
Lat. 65° 18′ N.

Orchidaceæ.

Cypripedium pubescens, Willd.
Lat. 65° 58′ N. Not before recorded in the north, west of the Rocky mountains.

Polygonaceæ.

Polygonum plumosum, Small.
Lat. 65° 18′ N.

[1] See Summary Report, Geol. Surv., 1911, pp. 21–26.

Caryophyllaceæ.

Stellaria longipes, Goldie var. *Edwardsii*, T. and G.
Lat. 65° 31′ N. and Lat. 65° 45′ N. New to the region.

Ranunculaceæ.

Anemone parviflora, Michx.
Lat. 67° N. Very large-flowered and possibly a distinct species.
Pulsatilla patens, L. var. *Wolgangiana*, (Bess.) Koch.
Lat. 67° 23′ N.
Pulsatilla Cairnesiana (Greene) J. M. Macoun.
Lat. 67° N., Lat. 67° 23′ N. and Lat. 67° 30′ N. Better specimens collected in 1912 at the above localities prove this plant to be a *Pulsatilla* rather than an *Anemone*. These specimens extend the range of this beautiful species to a point 80 miles north of where the type specimens were collected in 1911.

Fumariaceæ.

Corydalis sempervirens (L.) Pers.
Lat. 65° 18′ N.

Cruciferæ.

Cardamine digitata, Rich.
Lat. 66° 02′ N. A single specimen. Known only from Bear lake and Herschell island.
Melandion boreale, Greene.
Perfect flowering specimens were collected at latitude 67° N., 42 miles north of the locality at which the type of the genus was collected in fruit in 1911.

Saxifragaceæ.

Saxifraga Nelsoniana, Don.
Lat. 65° 58′
Saxifraga flagellaris, Willd.
Lat. 65° 18′. New to the region.

Gentianaceæ.

Gentiana arctophila, Griseb.
Lat. 65° 18′ N.
Gentiana prostrata, Hænke.
Lat. 65° 18′ N.
Gentiana frigida, Hænke.
Lat. 65° 18′ N. All three of the above gentians are additions to the known flora of the region, *G. prostrata* has only been recorded once before from the Alaskan boundary, and *G. frigida* not at all from the interior Yukon region.

Boraginaceæ.

Eritrichium nanum, Schrad. var. *Chamissonis*. DC.
Lat. 67° N.

Serophulariaceæ.

Pedicularis capitata, Adans.
Lat. 65° 58′ N.
Pedicularis sudetica, Willd.
Lat. 65° 58′ N.

Campanulaceæ.

Campanula N. sp.
Lat. 65° 18′ N. Apparently not nearly related to any of the known species.

Compositæ.

Erigeron N. sp.
Lat. 65° 18′ N.

ZOOLOGY.

(*P. A. Taverner.*)

During the year of 1912 the zoological staff has been directing its principal energies towards cataloguing the material already in the museum, and taking proper care of that received during the year. The former has included much more than merely numbering and listing the specimens. Partially and sometimes totally obliterated or incomplete data have had to be deciphered and verified by comparison with records scattered through files of many publications, manuscripts, and letters. In some cases considerable correspondence has been carried on and contributors interviewed before the necessary information has been obtained. Specimens from various sources have been brought together into their own accession groups, relabelled in non-fading india ink, and recorded in new catalogues specially designed for the purpose; after which they have been redistributed for temporary storage in metal boxes, and arranged according to their natural and systematic relationships in so far as possible under existing conditions.

All this has involved a great amount of careful and painstaking work that, while making little or no showing to the superficial critic, is of the utmost necessity to the future use of the material in hand. This work is well under way, though still far from complete.

The birds received prior to 1913 have all been catalogued. There are at present 6,105 mounted and study skins of this class in the museum. Like work upon the mammals is well advanced and nearing completion. The mammal skins are stored for the present in the same manner as the birds, the skulls and corresponding skins bearing duplicate numbers. These are placed in convenient and easily classified cardboard boxes or glass vials. The mammal specimens number about 1804.

Mr. C. H. Young has been doing similar work in cataloguing the invertebrates. He has finished the crustaceans, numbering 1,175, and the mollusca are well under way. Of the latter, the Canadian marine forms have been finished and a good start made upon the fresh water species. None of the foreign shell collection has been touched, which, filling fourteen of our standard wooden Survey boxes, still presents a considerable undertaking.

Besides the incomplete work above referred to there remain all of the insects, protozoa, and radiates among the invertebrates, and the fish, reptiles, and birds' eggs of the higher orders yet to be catalogued. This is, in all, more than sufficient work to keep the present staff busy at nothing but routine cataloguing for the next two years, giving no time for original or other work. It is evident from this how necessary is a considerable augmentation to our staff if our museum is to take its proper place among sister institutions.

In systematically going over the material in this way, it has developed that while we are rich in specimens from the International Boundary between Alberta and the Pacific coast inclusive, we have only a comparatively small representation from other areas. The east coast has contributed some small collections, mainly from Nova Scotia and New Brunswick, but they are far from comprehensive, and with the exception of a few scattering and individual specimens and the newly acquired southern Ontario collection to be mentioned later, we have nothing of importance from intermediate districts. Of northern material we have a small amount which the various members of the staff have brought in from time to time in the past.

Plans have been made and steps taken towards supplying the pressing need of storage cases for study material. It is hoped that the work will be pushed vigorously. We brought our specimens through last summer safely, but at the price of constant vigilance and with several narrow escapes.

Early in the year a set of instructions regarding the collection of zoological specimens was prepared for use by those collecting for us. This covers the zoological field quite thoroughly and has been the subject of some commendation by others experienced in the work. In the preparation of this I wish to thank Dr. A. G. Ruthven, of the Museum of the University of Michigan, for advice in the part relating to reptiles, and Dr. Bryant Walker who kindly allowed us to embody in the instructions his pamphlet on the collection of land and fresh-water shells. These instructions were not published early enough to be of service in this year's work, but will be available for use next season and I hope will be of considerable assistance to the Geological Survey staff and others who may be in the field collecting for us.

A new note-book for the recording of daily and other observations on the flora and fauna has also been prepared. These note-books should be of considerable value, as they admit of the recording of detailed daily notes with a minimum of time and can be kept up by members of the various staffs without interruption to their field work. By their use we expect to obtain exact data on comparative abundance and distribution of many species in many out of the way localities.

Besides the above the writer has been collecting the available data on the occurrence of bird life in the Dominion, and recording it in a card system under specific headings. Special attention has been given to the gathering of matter that did not appear in the 'Catalogue of Canadian Birds' or that has been published since. The system at present numbers about 2,500 cards and is growing rapidly. A card index of Canadian Ornithological Bibliography is also well under way, as well as like indices showing localities represented in our collections, contributors to the same, and a directory of Canadian naturalists. These are at present, of course, far from complete, but becoming more nearly so every day, and already their daily use indicates the value they will have when approximately comprehensive.

A start had also been made in the way of exhibition work, but owing to the lack of skilled preparators and the difficulty of deciding upon the type of case most desirable only temporary exhibits have been installed. Some of our mounted material consists of excellent examples of the taxidermist's art, but much of it falls below the standard in these days of elaborate group work, and few creditable exhibits can be installed until a properly qualified and experienced museum preparator is obtained. A group of musk oxen, collected by A. P. Low in 1904 near Wager inlet, Hudson bay, and mounted by Ward's Natural History Establishment has been cased and installed in the east wing of the first floor. Another group mounted by the same firm showing Dall's Mountain sheep is assembled and awaiting a case in the same hall. Besides these, a number of temporary exhibitions have been made showing a model of a proposed Atlantic coast group, various nesting habits of native birds, characteristic prairie animals, life histories of moths and butterflies, etc., and some crabs. These have been labelled with temporary typewritten labels that, while being accurate, are intended to be as entertainingly instructive as possible.

On November 11 the writer attended the annual meeting of the American Ornithologists' Union, at Cambridge, Mass., where he was joined by Mr. C. H. Young and a day was spent in studying the exhibition methods of both the Agassiz Museum and that of the Boston Society of Natural History. We then proceeded to New York and spent a week in the same manner at the American Museum of Natural History and the Brooklyn Museum. Free access was given us to all departments, and every facility given by both department heads and their staffs for studying details and technic of operation in the various departments. The

results were highly satisfactory and we gained much information that will be of use to us in the future.

With all this it was impossible for our limited staff to do any field work. Mr. Frank Hennessey, who was engaged to assist the division for a few months during the summer, collected some specimens afternoons after office hours, the museum supplying ammunition. The accessions obtained in this way while small are valuable, as much from our lack of local material as for the beautiful manner in which they are made up. The writer made one trip up the Rideau canal to the lakes of the same name for the purpose of studying the collecting possibilities of the region and to investigate a heronry in that neighbourhood. The latter was found occupied by about two hundred birds and will likely supply specimens for a habitat group of the species as soon as constructive work can be started on the exhibitions.

During the past year the collections have increased considerably by the receipt of small lots of specimens, but more especially through the acquisition of a rather large collection of birds and a few mammals from the southern extremity of Essex county, Ontario. These coming from a region hitherto unrepresented in our collections form a most valuable acquisition to the museum.

A considerable number of donations have come in during the year which are valuable as much from their number, which evidences the extent of the appreciation being shown to our institution by the public in general, as from their intrinsic value. An offer of a large collection of mounted birds and mammals has been made by Mr. J. H. Fleming, of Toronto, Ontario. This includes one of the most important collections of mounted birds in the Dominion, not only from the very high excellence of the work done on them but from the number of records and interesting specimens which they include. They will, however, arrive too late to appear in the list of accessions for 1912 or to be noticed in detail this year.

Outside of the Geological Survey many Government survey and exploration parties are sent into the field. If a naturalist could be attached to each important party, specimens might be gathered with a minimum of expense. The Canadian country is changing rapidly from an unsettled state to that of civilization and cultivation. This is having a most profound effect upon our flora and faunal life, and vast changes are being brought about in our biotal conditions. The old order is passing away, in many places has already passed, without leaving a record of its being behind. If the next generation is not to charge us with being indifferent to their interests we must improve every opportunity of making record of present conditions. The time for this work is now, for every day means some loss on the pages of our records that can never be filled.

Our study collections have been considerably used by experts outside the staff. Among those who have availed themselves of what facilities we had to offer were: Dr. C. Hart Merriam, who is making an exhaustive study of North American animals; Mr. Allan Brooks, of Okanagan Landing, B.C.; Mr. J. H. Fleming, of Toronto; Dr. J. A. Allen, who is preparing a monograph on the musk ox; Robt. J. Howards, of the British Ornithological Union; Prof. W. W. Cooke, of the United States Biological Survey; F. C. Hennessey, who made considerable use of our material in his colour studies of our Canadian birds; and others.

Accessions 1912.

By the Staff of the Natural History Division.

12-20.—By P. A. Taverner.—
One pair Baltimore Orioles, Ottawa, Ont., May 12, 1912.
Catalogue Nos. 6024-6025.

12-33.—By P. A. Taverner.—
Five bird skins, Kingsmere P. O., Que., May 12, 1912.
Catalogue Nos. 6064-6068.

12-35.—By C. H. Young.—
Birds in flesh, Meach lake, Que., Sept., 1912.
Weasel, same locality.
Catalogue Nos. (Birds), 6069-6072; (Mammal), 17099.

12-40.—By J. M. Macoun.—
Skeleton of Wolverine collected from cougar trap near discharge of Butlers lake, Strathcona park, Vancouver island, B. C., Aug. 3, 1912.
Catalogue No. 1801.

By the Staffs of the Other Divisions of the Geological Survey.

12-36.—By D. D. Cairnes.—
149 specimens of Lepidoptera.
1 head of Surf Scoter.
All taken on Alaska-Yukon boundary between the Porcupine and Yukon rivers the summer of 1912.
Catalogue No. (Bird) 6105.

12-41.—By D. B. Dowling.—
3 pictures of British Columbia mammals.

12-45.—By Percy Selwyn.—
One Pileated Woodpecker in flesh, taken Oct. 19, 1912, in the Gatineau district, Que.
Catalogue No. 6102.

12-50.—By D. A. Nichols.—
Virginia Deer, skull and horns picked up on Texada island, Strait of Georgia, B. C., summer of 1912.
Catalogue No. 1804.

By Transfer from Other Divisions.

12-5.—From Ethnological Division.—
Six teeth of Killer Whale from Wrangel, Alaska, 1894.
Catalogue No. 1782.

12-46.—From Palæontological Division.—
One fresh water shell from Lake Manitoba, Man., Sept. 10, 1912, collected by E. M. Kindle.

12-49.—From Palæontological Division.—
One Bison skull and horn case, collected by Chas. Sternberg, Drumheller, Alta., Aug. 1912.
Catalogue No. 1803.

12-29.—From Palæontological Division.—
Land shells from Young point, N. S., Cape Blane, Que., summer, 1912, collected by Percy Raymond.

By Presentation.

12-1.—By C. de B. Green, Okanagan Landing, B. C.—
One egg of Loon, collected 1907 at Osoyoos lake, B. C.

12-85.—By Geo. E. Sanders.—
Five molluscs from Grosse Coques, St. Mary bay, N. S., collected 1912.

12-4.—By W. G. A. Lambe, Toronto, Ont.—
Spirit specimen of body of Painted Snipe, showing interesting convolutions of windpipe, Melbourne, Australia, 1912.
Catalogue No. 4760.

12-7.—By A. M. Scott, Ottawa, Ont.—
Fine piece of 'brain coral' collected by donor, March, 1912, from the reef at Audros island, Bahamas.

12-8.—By F. C. Hennessey, Ottawa, Ont.—
Seven Redpoll skins representing three species and subspecies, viz, *Acanthus linaria linaria A. l. holboelli* and *A. hornemanni exilipes*, taken at Mattawa, Ont., March 12, 1912, by A. Benoit.
Catalogue Nos. 4762-4768.

12-10.—By F. C. Hennessey, Ottawa, Ont.—
Nine birds in flesh from Kingsmere, Que., March 12, 1912.
Catalogue Nos. 5976-5984.

12-13.—By F. C. Hennessey, Ottawa, Ont.—
Twenty Redpolls in flesh, March, 1912, Mattawa, Ont., taken by A. Benoit.
Catalogue Nos. 5991-6010.

12-14.—By..............—
One Flicker in flesh, Ottawa, Ont, March, 1912.
Catalogue No. 6011.

12-15.—By F. C. Hennessey, Ottawa, Ont.—
Pileated woodpecker in flesh, May 5, 1912, Kingsmere, Que.
Catalogue No. 6012.

12-16.—By F. C. Hennessey, Ottawa, Ont.—
Five birds from near Old Chelsea, Que., and about Ottawa, Ont., May, 1912.
Catalogue No. 6013-6017.

12-17.—By F. C. Hennessey, Ottawa, Ont.—
Three bird skins, May, 1912, from Dominion Springs, near Pakenham, Ont.
Catalogue Nos. 6018-6020.

12-18.—By Stuart Criddle, Treesbank, Man.—
Nest and eggs of Spragues Pipit, April 5, 1912, Treesbank, Man.

12-19.—By A. W. Oldfield, Powassan, Ont.
Three bird skins, Powassan, Ont.
Catalogue Nos. 6021-6023.

12-21.—By A. Robertson.—
One live bat, July, 1912, Plantagenet, Ont.
Catalogue No. 1795.

12-22.—By F. C. Hennessey, Ottawa, Ont.—
Two birds in flesh, July 29, 1912, Ottawa, Ont.
Catalogue Nos. 6026-6027.

12-23.—By John M. A. McArton, Carleton Place, Ont.—
One Carolina Dove, Carleton Place, Ont., Aug., 1912.
Catalogue No. 6028.

12-24.—By F. C. Hennessey, Ottawa, Ont.—
Two birds in flesh, Ottawa, Ont.
Catalogue Nos. 6029-6030.

12-25.—By Capt. Sorenson.—
Embryo whale from Altantic coast, in alcohol.
Catalogue No. 1794.

12-26.—By F. C. Hennessey, Ottawa, Ont.—
Four birds in flesh, Ottawa, Ont., Aug. 10, 1912.
Catalogue Nos. 6031-6034.

12-27.—By James Marshall, Ottawa, Ont.
Broad-winged Hawk in flesh from Meach lake, Que., Aug. 9, 1912.
Catalogue No. 6035.

12-28.—By F. C. Hennessey, Ottawa, Ont.—
One bee from Melville island, Franklin, July 20, 1909.
One bat, Ottawa, Ont., Aug. 1912.
Catalogue No. (Mammal) 1797.

12-31.—By Rev. J. H. Keen, Metlakatla, B. C.—
Egg of Black Oyster Catcher, Metlakatla, June, 1912.

12-32.—By F. C. Hennessey, Ottawa, Ont.—
Twenty-six birds in flesh from Ottawa, Ont., Aug. 1912.
Catalogue Nos. 6038-6063.

12-34.—By T. E. Lloyd, Ottawa, Ont.—
Skull of Black Bear, taken in Nipissing district, about 1892.
Catalogue No. 1798.

12-37.—By S. K. Burdin, Ottawa, Ont.—
One Bonaparte's Weasel in flesh, near Ottawa, Sept. 22, 1912.
Calatogue No. 1800.

12-39.—By A. Workman, Ottawa, Ont.—
One Hudsonian Curlew, Ottawa, Ont., Oct. 6, 1912.
Catalogue No. 6101.

12-43.—By Frederick Lambart, Ottawa, Ont.—
One Jaeger.
2 sets Ptarmigan eggs.
One gopher.
From Alaska-Yukon boundary, Lat. 69, summer 1912.
Catalogue Nos., (Birds), 6103, (Mammals), 1802.

12-47.—By J. H. Slack, Ottawa, Ont.—
One Butterball duck in flesh, Shirley bay, Ottawa, Ont., Oct. 25, 1912.
Catalogue No. 6104.

12-48.—By Jacob Smith, Aylmer, Que.—
One Milk Snake in flesh from Aylmer, Que., Nov. 9, 1912.

12-51.—By Frederick Lambart, Ottawa, Ont.—
Section of tree trunk with Flicker's nest, Ottawa, Ont., 1912.

By Permission.

12-44.—Of Maynard Rogers, Ottawa, Ont.—
Photographs of deformed feet of moose, showing over-grown hoofs.

By Exchange.

12-30.—From Rev. G. Eifrig.—
Two bird skins, Lake Dore, Renfrew county, and Doyle, Que., 1890 and 1912—more to follow.
Catalogue Nos. 6036-6037.

12-38.—From Henry K. Coale, Chicago, Ill., U.S.A.—
Twenty-eight bird skins, mostly from northeast Illinois and California, of various dates and collectors.
Catalogue Nos. 6073-6100.

By Purchase.

Accession Nos.

12-6.—From A. W. Oldfield, Powassan, Ont.—
One Juv. Great Grey Owl, *Scotiaptex nebulosa nebulosa*, taken in July, 1911, in Chisholm township, Nipissing district, Ont.
Catalogue No. 4761.

12-9.—From P. A. Taverner, staff.—
Entire private collection collected between 1904 and 1911 in southern Ontario and adjoining Michigan territory, consisting of 1,222 birds and a few small mammals.
Catalogue Nos., (Birds), 4769-5775; (Mammals), 1783-1792.

12-11.—From L. Renaud, Port Arthur, Ont.—
One pair interlocked Moose horns, collected in Feb., 1912, near Black bay, Lake Superior.
Catalogue Nos. 1793-1794.

12-12.—From Harry Williams, Niagara Falls, Ont.—
Six Whistling Swans in flesh, killed April 12, 1912, by being carried over Niagara Falls.
Catalogue Nos. 5985-5990.

12-42.—From Frederick Lambart, Ottawa, Ont.—
One Grizzly Bear skin and skull, killed on Alaska-Yukon boundary, Lat. 69°-0′-30″.
Catalogue No. 1763.

ANTHROPOLOGICAL DIVISION.

PART I.

ETHNOLOGY AND LINGUISTICS.

(*E. Sapir*).

Museum.

In the course of the year the exhibition hall of the Division of Anthropology has been provided with glass cases for exhibition purposes. Of these, thirty cases of 6 foot unit length (eighteen upright cases and twelve table cases) and five upright cases of double length have been set aside for exhibition of ethnological material, while eight table cases of unit length are to be utilized for the exhibition of archæological objects. Four wall cases and two upright cases intended to be placed in the corner alcoves of the hall have been ordered, but are still outstanding. In planning the selection of specimens that are to make up the regular ethnological exhibit, it soon became evident that the space allotted was too small for the adequate representation of the five main aboriginal culture areas of Canada, and it was decided to limit the hall to three of these ethnological areas (Eastern Woodlands, Eskimo, and West Coast), besides a synoptic survey of the archæology of the Dominion. The need for another exhibition hall to be devoted to the uses of the Division of Anthropology is urgent, as provision should be made for an exhibit of representative collections from the Plains and Plateau-Mackenzie areas, material from which it is expected will be coming in in increasing quantities. The first step taken in the preparing of a public exhibit was the suspending of the long Haida war canoe from the ceiling of the anthropological hall. It is intended, in the course of the next calendar year, to suspend in similar manner the heavier of the smaller canoes, which are to be placed near the walls of the hall. The exhibits representing the three culture areas referred to will be installed in the course of the year 1913 and systematic labels will be prepared to accompany them. Of the three large totem poles now owned by the museum, two (from Bellakula and from Massett, Queen Charlotte islands) have been placed at the entrance to the building; the third, a particularly high one from Skidegate, Queen Charlotte islands, has not yet been placed, and would be best provided for in a high hall which might at the same time provide for exhibits of Plains and Plateau-Mackenzie material.

Thus far the museum work of the scientific staff of the Division of Anthropology has been seriously hampered by the lack of a regular preparator or technical assistant, as the purely scientific and office work of the staff makes it difficult for them to do full justice to the proper care of museum material. The necessity for an anthropological preparator, whose duty it would be to treat (clean, fumigate, and poison), sort out, number, catalogue, store, and keep in constant good care the ever increasing anthropological collections of the museum, is imperative. Provision might also well be made for a skilful mechanic for the division, who could be employed to repair or reconstruct material in poor or fragmentary condition, prepare models and groups illustrating various phases in the life of the natives, and do such other technical work as might be required.

Museum Specimens.—Over 1,500 ethnological objects have been added in the course of the year to the collections of the museum. These were obtained either

by gift, by purchase in the course of regular field work for the division, by members of the Geological Survey not connected with the Division of Anthropology, and by purchase of material not directly obtained in connexion with field work. There have been obtained as gifts:—

From C. D. Melvill and J. Hornby, of Edmonton, Alberta, 30 ethnological specimens of the Pallirmiut Eskimo of Coppermine river.

From C. W. Drysdale, of the Geological Survey, wooden fragment from Spatsum, B.C.

Material was obtained in the course of regular field work for the Survey as follows:—

By E. Sapir—
- 26 Algonquin specimens from Maniwaki, Que.

By C. M. Barbeau—
- 140 Iroquois specimens, from Seneca Reservation, Oklahoma
- 71 Wyandot specimens, from Wyandotte and Seneca Reservations, Oklahoma
- 7 Wyandot specimens, from Amherstburg, Ont.
- 37 Huron specimens, from Lorette, Que.
- 4 Ojibwa specimens, from Amherstburg, Ont.

By W. H. Mechling—
- 2 Malecite specimens, from New Brunswick
- 5 Micmac specimens, from New Brunswick

By F. W. Waugh—
- 327 Iroquois specimens, from Iroquois reserves in Ontario, Quebec, and New York State
- 12 Ojibwa specimens, from the Chippewas of the Thames, Ont.

By A. A. Goldenweiser—
- 9 Iroquois specimens, from Six Nations Reserve, Ont.

By P. Radin—
- 1 Iroquois specimen, from Manitoulin island, Ont.
- 4 Ojibwa specimens, from Manitoulin island, Ont.

By J. A. Teit—
- About 30 Tahltan specimens, from Upper Stikine river

Ethnological specimens purchased in course of field work by members of the Geological Survey not connected with the Division of Anthropology are:—

By W. Leach, 1 pair of Stoney moccasins, from Morley, Alberta

By D. D. Cairnes, 12 Athabaskan specimens, from Yukon territory

Ethnological specimens that were purchased not immediately in connexion with field work are:—

From F. G. Speck, Philadelphia, Pa.—
- 377 Montagnais specimens from Lake St. John, Seven Islands, and Moisie, Que.
- 5 Naskapi specimens from Moisie, Que.
- 33 Abenaki specimens from Lake George and Adirondack mountains, N.Y.
- 31 Penobscot specimens from Oldtown, Maine
- 3 Huron specimens from Lorette, Que.
- 16 Eskimo specimens (Labrador, Baffin Land, and Alaska)
- 2 Tlingit specimens from Alaska
- 3 Têtes de Boule specimens from St. Maurice river, Que.

5 miscellaneous specimens (Cree, Nanticoke, Mohegan, and Pamunkey)

From Chief John Gibson, Six Nations Reserve, Ont.—
83 Iroquois specimens

From A. B. Reagan, Nett L., Minn.—
113 Ojibwa specimens from Bois Fort Reservation, Minn.
9 Quileute specimens from Lapush, Wash.

From Chief James Paul, St. Mary, N.B.—
13 Malecite specimens

From Mrs. C. Michel, River Desert Reserve, Que.—
69 Algonquin specimens

From Mrs. M. Thompson, Hull, Que.—
2 Iroquois specimens

From Nicolas and Caroline Groslouis, Lorette, Que.—
15 Huron specimens

From R. S. Kariho, Roswell, New Mexico—
9 Wyandot specimens from Oklahoma

From Miss N. Dawson, Wyandotte, Okla.—
4 Wyandot specimens from Wyandotte Reservation, Okla.

From John Lewis, Brinsley, Ont.—
3 Ojibwa specimens from region of Lake of the Woods

The greater part of the ethnological museum material obtained is thus from the Iroquoian (Iroquois proper, Wyandot, Huron) and Algonkian (Montagnais, Ojibwa, Algonquin, Abenaki, Penobscot) tribes of the Eastern Woodlands area. The parts of Canada that at present most sadly need representation in the Anthropological Division of the museum are the Plains, Western Plateaus, and Mackenzie valley. Part of the Eskimo material recently acquired by Mr. V. Stefánsson from the Eskimo of Coronation gulf and adjoining regions is designed to be turned over to this museum, but the material has not yet been received.

Photographic Work.—Photographs of ethnological interest have been received by the Division of Anthropology during the course of the year, partly by gift, and partly as a result of field work undertaken by the division. A complete set of prints is filed with the Anthropological Division. The gifts are as follows:—

From University of Pennsylvania, Philadelphia—
116 Montagnais photographs from Lake St. John, Que.
119 Penobscot photographs from Oldtown, Maine
22 Micmac photographs
2 Huron photographs from Lorette, Que.

From F. G. Speck, Philadelphia, Pa.—
128 Montagnais photographs from Lake St. John, Seven Islands, and Moisie, Que.
14 Penobscot photographs from Oldtown, Maine
2 Micmac photographs
6 Wyandot photographs

From C. D. Melville, Edmonton, Alberta—
8 Coppermine River Eskimo photographs
9 Dogrib photographs

From Stephen Retasket, Lillooet, of Lillooet, B.C.—
24 Lillooet photographs

From Mary Logan, Seneca-Wyandot, of Oklahoma—
2 Wyandot and 2 Iroquois photographs

From Catherine Johnson, Wyandot of Oklahoma—
1 Wyandot photograph

From Mary Turkey, Wyandot of Oklahoma—
- 11 Wyandot photographs

From A. B. Reagan, Nett L., Minn.—
- 1 Ojibwa photograph

Ethnological photographs taken by members of the anthropological staff in the field or at the museum, and by the Photographic Division of the Geological Survey are as follows:—

By C. M. Barbeau—
- 185 Wyandot photographs, chiefly from Wyandotte Reservation, Oklahoma
- 188 Iroquois photographs, chiefly from Seneca Reservation, Oklahoma
- 7 Interior Salish (Okanagan, Thompson River, Shuswap, Lillooet) photographs
- 1 Ottawa photograph, Wyandotte Reservation, Okla.

By F. W. Waugh—
- 108 Iroquois photographs from Iroquois reserves in Ontario, Quebec, and New York state

By F. H. S. Knowles—
- 21 Iroquois photographs, Six Nations Reserve, Ontario

By Photographic Division, Geological Survey—
- 7 Malecite and Micmac photographs
- 49 Interior Salish (Okanagan, Thompson River, Shuswap, Lillooet) photographs

From these photographs seven lantern slides have been made and added to the stock kept by the division for lecture purposes. Of these, four are Huron and Iroquois, and three Interior Salish (Thompson River, Shuswap, Lillooet).

Phonograph Records.—The recording of aboriginal music, begun from the very start of the research work of the division, has been continued throughout the year. The following records have been made by members of the permanent and field staffs and deposited in the museum:—

By C. M. Barbeau—
- 103 Iroquois (Cayuga-Seneca) records from Seneca Reservation, Oklahoma, embracing 231 songs and 5 speeches and prayers
- 32 Wyandot records from Wyandotte Reservation, Oklahoma, embracing 40 songs and 6 language records
- 5 Shawnee records from Wyandot Reservation, Okla., embracing 6 songs
- 41 Interior Salish (Thompson river, Shuswap, Lillooet) records taken in Ottawa, embracing 37 songs and 2 speeches

By A. A. Goldenweiser—
- 40 Iroquois records from Six Nations Reserve, Ont., embracing 74 songs

By E. Sapir—
- 3 records from Chief John Gibson, Seneca of Six Nations Reserve, Ont., taken in Ottawa, embracing 6 songs
- 2 Ojibwa language records, taken in Ottawa from Edwin Maness, Ojibwa of Sarnia Reserve, Ont.

By J. A. Teit—
- 61 Tahltan songs from Upper Stikine river

Of this phonographic material, Mr. Barbeau's 231 Iroquois songs and 6 Shawnee songs have been transcribed into notes by J. D. Sapir, and are thus better available for study in connexion with ethnological research.

Field Work and Research.

Ethnological research work in the field has been diligently prosecuted during the year. Besides the field research undertaken by Mr. C. M. Barbeau, of the permanent staff, the services were procured also of Dr. A. A. Goldenweiser, Mr. F. W. Waugh, Mr. W. H. Mechling, Dr. P. Radin, and Mr. J. A. Teit. Mr. Barbeau spent about four months in Oklahoma and at Amherstburg, Ontario, in continuation of his Wyandot ethnological and linguistic work of the preceding year. Dr. Goldenweiser continued his field research on Iroquois social organization and religion, spending about three and a half months at Six Nations Reserve, Ontario, for this purpose. Mr. Waugh undertook an elaborate investigation of the material culture of the Iroquois Indians, visiting Six Nations Reserve and Oneidatown in Ontario, Caughnawaga in Quebec, and Tonawanda and Onondaga Castle in New York state, and devoting an aggregate of nearly eight months in the field. Mr. Mechling continued ethnological research among the Malecite of New Brunswick, devoting an aggregate of two months in the field to the work. Dr. Radin undertook the study of the Canadian Ojibwa on the side of social organization, mythology, religion, and language, visiting several reserves in Ontario, and spending five months in the field. Mr. Teit began what is expected to be a thorough reconnaissance of the comparatively little known Athabaskan tribes of the Western Plateaus by spending a little over two months among the Tahltan Indians of the Upper Stikine region, B.C. In the early part of the year Mr. Teit visited Ottawa as spokesman of a delegation of Interior Salish chiefs who had come on administrative business. The opportunity was taken by Mr. Barbeau to secure photographs and phonograph records from a number of these, and to make a study of a special phase of the social and religious life of the Thompson River and Lillooet Indians. Reports of these various lines of research work are appended. Mr. V. Stefánsson returned during the year from his four years' exploratory and ethnological trip in the Arctic north; a general account of the ethnological results of the expedition is appended. A short trip for the purpose of collecting Algonquin museum material was made by myself among the Algonquin Indians living near Maniwaki, Quebec.

Manuscripts.—Manuscript material of ethnological interest was obtained during the year, partly by gift, partly by purchase. The gifts embrace:—

C. D. Melvill—

Notes on the Coppermine River Eskimo and their neighbours, manuscript of 7 pages

The manuscript material purchased embraces:—

A. B. Reagan—

Material on Ojibwa names, mythology, birch bark drawings with explanation of symbolism, and drawings of petroglyphs on Picture island, Bois Fort Reservation, Minn.

Manuscript and figures on Ojibwa and Quileute games

Manuscript and figures (including birch-bark drawing) of Ojibwa Ogechedah dance

L. L. Thompson, Iroquois of Lake of Two Mountains, residing at Hull, Que.—

590 pages of Mohawk text, chiefly folk-lore, written down by himself

Though not strictly applying to this year, mention should be made of the gift in 1911 by Dr. F. Boas, of Columbia University, of valuable manuscript material on the Nootka Indians. This material embraces linguistic notes collected by Dr. Boas years ago for the British Association for the Advancement of Science and only in part published in their reports; 5 pages of data on the Nootka Whaling Ritual, obtained for Dr. Boas by George Hunt; and, most important of all, 333 pages of mythological manuscript obtained by George Hunt from the Nootka Indians of Nootka sound. It is intended to prepare these Nootka myths for publication by the Survey.

A paper on 'Some Aspects of Puberty Fasting among the Ojibwa,' based on the results of his Ojibwa field work, has been submitted by Dr. Radin, and will be published in one of the numbers of the Museum Bulletin.

ON IROQUOIAN FIELD-WORK, 1912.

(*C. M. Barbeau*)

The additional period of about four months' field-work in Quapaw Agency, Oklahoma—extending from April to August, 1912—has proved of real profit for the ethnographic study of the Wyandots and of their neighbours and kinsmen, the Cayuga-Senecas. The nature of the material collected during this period will be briefly described.

Wyandot Work.

About three months and a half were taken up by the study of the mythology and folk-lore, social organization, feasts and rituals, technology, and language of the Wyandots (or western Hurons). The bulk of this year's results pertains to their mythology, linguistics, and technology.

The principal informants utilized were Catherine Johnson, Allen Johnson, Henry Stand, B. N. O. Walker, Smith Nichols, John Kayrahoo, Star Young, and Maggie Coon, of Wyandotte Reservation, Oklahoma, and Mary McKee, of Amherstburg, Ontario.

The recent additions to the mythology, folk-lore, and heroic traditions are numerous and valuable in many respects; and thirty-five out of over forty-five narratives have been recorded in text form with interlinear translations.

Sixteen narratives deal with the mythical origin of various natural and sociological phenomena. The origin of the world, of the constellation of seven stars, and of the peals of thunder sometimes accompanying a sun-shower, are described: the world (or 'the island') as having bęen created on the Big Turtle's shell, after the downfall of a woman from the sky; the seven stars as being the seven brothers that ascended into the sky while dancing, after a prolonged fast; and the sun-shower peals of thunder as being caused by the impetuous son of the Thunder and a Wyandot woman of former times. The narratives concerning the origin of sociological facts relate, first, the mythical contests between the Big Turtle and several animals, which account for the priority of rank claimed by the Big Turtle clan over the other clans, and, second, the heroic adventures in the course of which privileged human beings have secured the protection of manitous (or totems). The mythic adventures accompanying the appearance of the manitous are of two slightly different types, characterized by the transfer of 'powers' and charms either to a single protégé for his own exclusive benefit, or to one or several protégés for the advantage of several. The myths of the first type tell how the Eagle, the Wolf, the monster Lion (referring to the puma, or 'felis concolor'), the Rabbit, the Maple-Tree, and a Tikẽ'ã (a fairy-like being) came to their protégés and gave them instructions accompanied by a charm, meant for their own exclusive use. The taboos of secrecy or of not killing the totem are mentioned, but disconnected from one another, in the Wolf, the Lion, the Eagle, and the Fairy myths. The adventures of the second type are those which took place for the benefit of a number of individuals collectively. The Snake myth (two additional versions of which have been taken down) explaining the origin of the Snake clan, and a tradition of the appearance of the White Otter to a woman of the Big Turtle clan to whom it gave the Ustura' dances, or the Big Turtle clan's ritual, bear reference to the clans as having enjoyed the protection of supernatural beings. The Flying-Lion,

the Beaver, and an invisible monster, on the other hand, are described as having protected one or several human beings in their fights against the gigantic Ground-Squirrel, the Spotted Snake, and a buried human monster. The remains of these are said to have been burnt and used by several people as charms, the efficiency of which was limited to special and beneficent purposes. Another myth of a different type accounts for the invention and subsequent use of a well-known remedy against small-pox, derived from the mythical league and strife between the pole-cats and the new disease, at the time when the white people were first seen.

The folk-lore and heroic traditions may be studied to still better advantage in the rather voluminous stories concerning the giants, the deeds and contests of heroes, sorcerers and witches, the fabulous adventures of animal characters, and the traditions concerning several wars of the past. The nature and habits of the mythical giants are further illustrated in three comparatively short narratives. The quasi-epic deeds and contests of heroes, sorcerers and witches, are related at considerable length in the following stories: that of the ill-treated step-son who became a prosperous Indian with the help of his manitou, the Steer; of the uncle and nephew whose rivalry and strife resulted in the ultimate success of the latter, owing to the interference of three manitous in turn; of the suitors and the old witch whose mischievous 'powers' were drawn from the White Bear monster; of the two cousins—one of whom was a cannibal—their trials and tribulations due to a witch, their mother-in-law; of Tatẽria, a sorcerer, and his brother, a hunter, who finally overcame a witch and her brother, a professional gambler; of the many pranks that the Trickster played upon a covetous old woman; and of the destruction of a witch who had assumed the form of a hen in order to practice her harmful art. One of two other stories constitutes a second and more modern series of episodes consisting of the clever tricks of Tuñẽtawidi'a, played on other people; the other, probably of foreign origin, is a satire on a simple-minded fellow. In several other tales, the principal characters are animals, otherwise behaving like men. To this category belong the story of the Deer and the Owl, several episodes of the Fox and Raccoon tricks, the Rabbit and the Wolf, and a few others. A good many interesting old-time customs and beliefs are also to be noted in several legends and anecdotes, such as: the destruction of horned snakes in a cranberry patch; the appearance of a wild cat with a bleeding scalp as a bad omen; the rituals that a hunter and his wife once performed during a famine in order to get a good hunt; the troubles and trances caused by a deceased hunter who had been improperly buried in the woods; the alleged superiority of Indian medicine-men over white physicians as revealed by their successful treatment of an Indian girl, whose illness was the result of the violation of a religious duty; and, among other things, a description by an old hunter of the way in which he once secured a huño^{n}t or small deer charm, as well as other of his recollections as a professional hunter. Isolated and fragmentary explanations bear upon many other aspects of the folk-lore, namely, the puberty seclusion of girls, the getting and transmission of charms, a charm in connexion with thunder, and so on.

The heroic traditions of the tribe have almost all vanished from the memory of the present survivors, and only five narratives could be taken down. These are: the wars of the Wyandots against the Senecas, against the Cherokees—in which the Thunder is said to have interfered in favour of the Wyandots, against the English, and against the Pawnees; and a tradition relating the first meeting of the white people and the Delawares, and the prophetic reproaches addressed to the Delawares by the Wyandots for their leniency towards the invaders.

To sum up, it may be stated that this body of mythology and folk-lore (regardless of its linguistic import as text material) is especially valuable not only as affording an excellent field for the study of Wyandot psychology, but also as

including a large number of interesting data on their mythical history, the manitous or totems and their function, the deities, heroes, sorcerers and witches, the art of witchcraft, the preparation and use of charms, and, to omit several other topics, on the hunting, burial, and war customs of former times.

Considerable time has been devoted to the study of the Wyandot language, and the indispensable linguistic data have been secured either in the form of texts with literal translations, or in direct investigation in the course of, first, a close analysis of the texts and about seven hundred individual names, and, second, the collection of a fairly large number of paradigms; that is, the full or partial conjugation of radicals with pronominal prefixes.

Allen Johnson deserves special mention for his meritorious assistance both as interpreter and informant on linguistics. Henry Stand, Eldredge Brown, and Mary Kelly had, previously, been used for the same purpose, but with less satisfactory results.

A complete grammar and study of the phonetics, and an extensive vocabulary may, presumably, be worked up out of the material now at hand. A large number of paradigms pertain to the following categories: subjective pronominal elements prefixed to verb radicals, conjugated in the present, perfect, and future tenses; compound objective and subjective pronominal elements with verb radicals, mostly all in the present tense; possessive pronouns with noun radicals, and nouns followed by verbal adjectives; possessive and personal pronouns in connexion with, apparently, three classes of terms of relationship; and, finally, subjective pronouns prefixed to compounded noun and verb radicals.

Classificatory work on these data has since been taken up with very encouraging results. All the paradigms of the subjective pronominal elements prefixed to verb radicals belong to two distinct classes of five conjugations each. The first class consists of five series of fifteen pronominal prefixes, and the second class of five series of eleven. While four pronouns in the singular, five both in the dual and plural, and one indefinite, are found in the conjugations of the first class, those of the second class consist of four, two, four and one persons in the singular, the dual, plural, and indefinite, respectively. Every conjugation of the second class, moreover, corresponds to one of the first class, and a radical may, under certain circumstances, pass from a conjugation of the first class into the corresponding one of the second, as in other Iroquoian dialects.

These paradigms, although strictly analogous to, and parallel with, those of other Iroquoian dialects, reveal greater complexity owing to specialized phonetic rules peculiar to Wyandot. The second and fourth conjugations of the first class, for instance, are each divided into three sub-conjugations, and the fifth into two.

It may be pointed out, at once, that all the radicals or stems belong exclusively to one conjugation of the first or the second class, according to the nature of their initial elements; in other words, if the stem itself begins with a vowel or a consonant it will belong to the conjugation that is characterized by that vowel or consonant as initial. The stems in *a*—, for instance, belong to the first conjugation; those beginning with a consonant belong to the second, and with *i*— to the third. The fourth is made up of the stems in *e*— and ^{e}—, and the fifth of those in *u*— and o^{n}—. In the second conjugation, besides, a contracted series (termed sub-conjugation) is found in connexion with stems beginning with *d*— or *n*—, *r*—, and original Iroquoian *y*.

Several series of *t*— and *s*— prefixes, combining with the various pronominal elements, cause a number of interesting modifications that have proved of value in the discovery of a number of important phonetic rules.

The tabulation of the composite objective and subjective pronouns has not yet been completed, and the thorough elucidation of other pronominal elements

and of grammatical, syntactic, and phonetic rules will depend upon further inductive work on the material already available.

The study of the technology and material culture has progressed quite satisfactorily. Over eighty specimens, connected with other data, pertain to the ethno-botany of the tribe, and about a hundred and thirty other miscellaneous articles are illustrative of the following arts and crafts: the methods, weapons, and objects connected with transportation, hunting, war, sports, and witchcraft; the utensils and other items of domestic utility, such as houses, traps, baskets, paddles, spoons, pestle and mortar, toys; and the various articles constituting men's or women's attire, for instance, moccasins, leggings, coats, sashes, head-dresses, and pouches.

While most of the ethno-botanical specimens and data at hand are connected with medical treatments, a few are illustrative of foods, dyes, and textiles. Most of the medicinal treatments connected with plants seem to rely upon the direct efficiency of the plant itself, by means of decoctions or poultices obtained therefrom. The quality of others, however, depends upon either their magical properties or some ritualistic device.

A number of interesting specimens prepared for the Museum by Maggie Coon, Catherine Johnson, and Becky Dushane, of Oklahoma, and Caroline Groslouis, of Lorette, will allow a fairly extensive study of the decorative arts, in the form of bead, moose-hair, porcupine quill, and ribbon appliqués. Decorative patterns in connexion with silversmithing, wood and bone carving, although rather scanty, are not altogether wanting. Many interesting old articles of the same kind have, besides, been examined in the United States National Museum in Washington (a number of moose-hair embroidered moccasins, evidently of Lorette make, collected by Catlin, about 1835), in the University of Pennsylvania Museum in Philadelphia, the American Museum of Natural History in New York, and the Art Gallery of Detroit.

Remarkable conservatism is characteristic of the decorative arts of the three bands of the Hurons, as most of the patterns or designs made at Lorette, Anderdon, Kansas City, and Wyandotte are either identical or strikingly analogous, notwithstanding different surroundings and foreign influences exerted in the course of over two centuries and a half of isolation, and the substitution of different kinds of raw material to work with. While most of these patterns represent flowers, leaves, and animals (some of the clan totems), another probably refers to a mythological subject. Other patterns are geometrical figures or borders of various kinds.

The only further accessions for the study of music consist of about forty songs recorded on the phonograph with John Kayrahoo, of Wyandotte, Oklahoma, and an Indian flute made by old Smith Nichols.

Comparatively little new material has been forthcoming on the social organization, government, and the feasts and rituals, as special attention had been directed to these topics in the previous period of field-work.

With regard to the social organization, some time has been spent on the elucidation of certain problems on the heraldry, the retranslation and linguistic analysis of individual names, the question of priority of rank of the Big Turtle or the Deer clans (the heads of the two phratries respectively), and the terms of relationship.

A close analysis and retranslation of the traditional individual names belonging to each clan has borne out the fact, already pointed out in last year's report, that most of these names refer either to the eponymous animal (or clan totem) and the mythology of the clan, or to some characteristic trait or deed of an ancestor within the clan. The most trustworthy informants, in this respect, are under the constant impression that all these names refer or should refer to the totem, which

—as above stated—is by no means always the case. In the course of this analytical work on over six hundred names, collected last year at Anderdon and Wyandotte, it has been observed that a small number of names were now embodied in the current stock of names of the present-day clans that had formerly belonged to the now extinct Hawk, Beaver, and Prairie Turtle clans. It was gratifying to find that over a hundred Lorette individual names, copied down from the old parish registers, could be recognized and translated by the Oklahoma interpreters, notwithstanding their faulty phonetic spelling. Many of these names are the same as those used by the western Hurons and belong to the Turtles, Bear, Deer, and Wolf clans; whereby it becomes clear that these names were used or known in various sections of the nation at the time of the final dispersion, in 1648.

Further information on several rituals, already studied last year, has been taken down. According to the old-time Wyandot calendar, the year seems to have been formerly divided into four seasons and thirteen moons; the Green Corn thanksgiving feast, held in the first full moon of August, apparently marking the end of the year. Three ancient rituals (the Big Turtle clan's ritual, that of all the clans assembled together, and a scalp dance) have first been called to our attention only as late as this summer, the informants knowing of their former existence merely by hearsay. The Big Turtle clan's ritual, termed the ustura' dance, used to take place at the time of the Green Corn feast, although it was, in former times, held independently. This ritual is said to have originated from the mythical White Otter who appeared to a secluded woman of the Big Turtle and gave her a series of dancing songs—five of which have been recorded on the phonograph—and directions, meant to be transmitted to the people of the Big Turtle clan. Of the scalp dance, performed in the course of a war expedition, only three songs and some details could be remembered. The nature of another interesting ritual—termed a'stayaérati—could not be fully ascertained, notwithstanding fairly extensive descriptions on the part of three independent informants. It is stated to be the clan's communal feast (perhaps a feast of the confederation of the clans), in which all the clans shared and had to be represented by one or several members respectively; each clan having, moreover, a distinctive song, four of which have been recorded, for the use of its own members.

Some practices and rituals accompanying the removal of disease from a patient, the gathering of plants for medical purposes, the selection of a wife for a chief's son, have also been briefly studied, as well as the games of ball and racket for women, the lacrosse game for men, and eighteen songs for the moccasin game.

About a hundred and eighty kodak photographs (portraits of adults and children, pictures of houses, traps, moose-hair patterns, and other articles) may also be mentioned here as part of the ethnographic material now available for the preparation of the final reports on the ethnography of the Hurons and Wyandots.

Cayuga-Seneca Work.

An excellent opportunity offered itself, in the course of field-work among the Wyandots of Oklahoma, for some incidental research among their close neighbours and kinsmen, the Cayuga-Senecas, of Seneca Reservation, Oklahoma. Specimens have, therefore, been collected, pictures of individuals and views of ritualistic performances taken, and a number of ritual and other songs recorded on the phonograph and explained.

With a view to gaining a clearer insight into some of the Wyandot rituals, it was deemed advisable to study, at least briefly, some of the similar feasts that are still carried on among a people that has long been closely associated with them,

especially in order to ascertain whether any of the material so far gathered among the Wyandots had been ascribed to its proper source. The space of altogether less than a fortnight has been spent on this investigation with the well-informed Cayuga head-chief, James Logan, his wife acting as interpreter. It has proved most fruitful in so far as, first, about two hundred and forty Cayuga ritual and dancing songs have been taken down on the phonograph—all of which have already been transcribed by Mr. J. D. Sapir of Philadelphia, Pa.—together with extensive notes on the method of dancing and the nature of each song and ritual; second, the individuality of both sets of Wyandot and Cayuga feasts has been clearly ascertained; and, third, an interesting light has been cast thereby on certain Wyandot rituals, the meaning of which became clearer when their Cayuga counterparts were explained. These Cayuga songs fall under three headings: the ritual dancing songs—constituting the bulk, the 'stamp' or 'stump' dances, and a few lyric songs.

The ritual songs, grouped in several series of about ten to twenty songs each, belonging to as many distinct feasts, will be published as an integral part of a sketch dealing with the nature and circumstances of the feasts, as described by the same informants. These songs all pertain to the following ceremonials, namely: several thanksgiving or 'first fruits' rituals, the White Dog sacrifice, a naming and an adoption feast, a dance in commemoration of a mythical event connected with all the clans, and, finally, a bear's head ritual. The 'first-fruits' or thanksgiving rituals observed are the Green Corn, the Strawberry, the Sun, and the Blackberry or Moon dances. These were all intended as a return of thanks to the Great Spirits, apparently embodied in the Sun and Moon, for the harvest of Indian corn, cereals, squashes, and fruits, and, also, as a request for the continuance of the same favours, general or special, during the following seasons. The Green Corn dances, formerly held on the first full moon of August, included several series of dancing songs, of which three series, containing thirty-seven songs, have been taken down. The first of these series was performed in the morning, the second after a naming ritual, and another, termed 'the Beans dance', was performed at night. Twelve songs and a set speech of thanks belonging to the Sun dance (generally termed 'war dance,' although not quite accurately) have also been recorded on the phonograph. As this feast was actually witnessed in October of the previous year, notes and photographs also are now at hand. The Blackberry dance, taking place at night on the full moon of July, was begun with an evening series of songs and wound up, in the morning, with three calls to the moon and another series of songs, thirty-six of which have been recorded. In the course of the same night, several 'stump' dances were taken up for the entertainment of the crowd. The Strawberry dance—performed in the afternoon, early in June of this year—was witnessed with profit, and a number of pictures of the ceremonials were taken; fourteen songs and a set prayer were also repeated on the phonograph by James Logan.

In the course of the Green Corn feast a naming ritual was formerly held between the first and second series of Green Corn dances, for the transfer of traditional individual names to the yet unnamed children of each clan, or the occasional substitution of another name by some adults. Each clan had a series of naming songs of its own, one of which had to be sung while a name was conferred. Fifteen of the Deer clan's songs have been secured.

Only three songs could be thought of that formerly belonged to the secret commemoration feast of the clans, termed atihi'tu's. An account of the myth of origin and, also, of some of the ceremonials, has been taken down. While a fairly extensive description of the White Dog sacrifice, accompanied by the only three songs belonging to it, has been given by James Logan and his wife, almost no in-

formation at all could be had on the bear's head dance, in connexion with which seven songs were remembered.

The sixty-eight 'stump' dancing songs for social entertainment, all but fourteen of which have also been sung by James Logan, consist of the following series: one performed in the evening (after the 'Seed dances') at the Green Corn feast; another old dance for women only; a characteristic dance for men and women, meant to stir up the sleepy dancers at night; and, finally, two other sets, the Fish and Raccoon 'stump' dances, the last of which was recorded with John Kayrahoo.

The eleven lyric songs obtained are interesting on account of their having been composed in a thoroughly Iroquoian style about fifty years ago by James Logan himself, who meant them as drinking songs.

The hundred and thirty-five Cayuga specimens, all accompanied by explicit data, illustrate various aspects of their ancient technology. While some pertain to their rituals, their aesthetic arts and games, others were meant for domestic use, warfare, and transportation. Twenty-four of these articles are of ritualistic significance, namely, the decorated paddles, spoon and basket used in the White Dog sacrifice, masks, rattles, head-dresses and an old Sun emblem, formerly used either in medicine practices, the Sun feast, or other ceremonials.

The aesthetic arts and the games are illustrated by about twenty-five objects, such as flutes, embroidered specimens, silver work, dolls, and several rackets, balls, and wooden bowls, the last of which were used in the games.

Of the implements and tools connected with domestic utilities, the splint baskets, bark trays, hominy sieves, and ladles are the best represented. Articles of clothing (moccasins, sashes, garter, coats, and leggings), weapons for warfare or hunting (war clubs, bows and arrows), models of canoes, paddle, house, cradle-board, and so on, conclude a list of interesting specimens available for exhibition purposes or for the study of comparative Iroquoian technology.

About a hundred and seventy-five photographs—the bulk of which are portraits of Oklahoma Cayuga-Senecas, and the remainder photographs of their Strawberry ritual—have also been taken and are now filed away at the Museum.

ON INTERIOR SALISH WORK, 1912.

(*C. M. Barbeau*)

A brief study of the cna'^{a}m (or 'individual totems') and songs of the Interior Salish Indians, of British Columbia—consuming altogether less than ten days, in the earlier part of January, 1912—was occasioned by a delegation of chiefs from British Columbia waiting upon the Dominion Government on official business. Through the kindness of Mr. James Teit, their interpreter, research work was at once taken up with Chief Tetlenitsa, an excellent Thompson River informant, Mr. Teit himself acting as interpreter, and Ignace Jacob, a Lillooet.

Thompson River.

The Thompson River (or Ntlakapamux) ethnographic information was obtained exclusively from Chief Tetlenitsa and Mr. Teit; Mr. Teit speaks the Thompson River Indian language and has become thoroughly acquainted with their institutions, in the course of twenty-eight years residence among them. This material consists, first, of discussions on the cna'^{a}m, what they prove to be, how and when they appear to their protégés, and their gifts to them; second, of about twenty-five dream and lyric songs recorded on the phonograph, almost all of which are accompanied with words that have been carefully written down phonetically, and translated with the help of Mr. Teit.

(*a*) The Thompson River cna'^{a}m is a 'totem' or mythical guardian whose protection, emblems, and instructions seem always to be intended for the exclusive benefit of a single individual. No attempt was made to get any extensive list of cna'^{a}m, as Mr. Teit himself had covered this field in a publication on the same tribe. The only cna'^{a}m explicitly referred to or described here by Chief Tetlenitsa and Mr. Teit were Coyote, the Loon, the two Black Bear Sisters, the Old Man, the Lizard, the Wolf and Hawk, the Ptarmigan, the Prairie Chicken, the Grass and Wind, the Cloud, the Mountain Peak, the Gun, the Arrow, and the Stump.

The cna'^{a}m appears to his protégé in the course of puberty training and, also, though seldom, on some subsequent occasions. The period of puberty training may last as long as twenty-five years, according to the calling of the novice; and it seems that the cna'^{a}m comes bodily to his protégé with a view to instructing him, especially during the periods of from two to ten days fasting incidental to the puberty training. When, later in life, on rare and special occasions, the cna'^{a}m actually appears to the protégé, it is to give him warnings of danger and appropriate directions.

Some interesting points have come out regarding the manner in which the cna'^{a}m appears to his protégé, and his way of introducing himself. The apparition may take place in two different ways, first, in a 'dream' (ci'kwalaux), and second, in a 'vision' (cwawi̊kŭm, from wi̊kŭm 'one sees'). By 'vision' is meant an actual and impressive appearance of the cna'^{a}m, in a human form, to a protégé, who is, at the time, awake and fully conscious of what is happening. A 'dream' means, here, a similar appearance, but to the protégé when asleep. The cna'^{a}m, although externally always a human being, is claimed to be more than a mere human being or animal, on account of its altogether superior 'powers'. It may appear bodily to the novice, sometimes in 'dreams,' sometimes in 'visions,' or it may simply converse with the novice without being seen at all. The greater the 'powers'

(or 'mana') of the novice become, the more intimate and prolonged have to be his acquaintance and familiarity with his mythical guardian. When the period of training is over, the cna'ᵃm very seldom appears in a 'vision', although more frequently in 'dreams'. Cases are also mentioned where some protégés, for improper conduct or the lack of observing taboos, have been altogether abandoned by their protectors. Whenever the cna'ᵃm makes its appearance, the protégé is always addressed with the formal words, 'I am the Bear . . . , the Cloud,' or whoever it may happen to be, in order that it may be recognized. Before stating what gifts and instructions are generally received from the cna'ᵃm, it may be noted that, as a rule, the novice has to relate in public his adventures with his guardian, as soon as his seclusion is over.

A novice is said to become lucky in his undertakings, endowed with a long life, and immune against all kinds of accidents as soon as he gets a sufficiently powerful cna'ᵃm, the instructions of which have, in fact, to be scrupulously observed. The instructions that the protégé receives from his cna'ᵃm pertain to the following topics: the choice of a career, the selection of a name, of body paint and paraphernalia, the observance of certain taboos of either a positive or a negative nature, and, if the novice is to become a medicine-man, the methods of healing the patients. A 'dream' song, considered as endowed with magical efficiency, is, besides, received in the same way.

The puberty training customs are said to be part of the ancient schooling system of the Salish, the cna'ᵃm being a real, as well as mythical, director of the course which the education of the novice is to assume. The calling of a young man is often decided upon by his guardian quite regardless of his own wishes or ambitions. The individual name bestowed upon the novice is either that of his personal totem or another one selected by the totem. The instructions regarding emblematic paintings and paraphernalia seem important and interesting. They may refer to the style and subject to be used either in painting one's body or articles in one's possession. Some of these paintings represent the totem; others are meant to operate by means of sympathetic magic. Mr. Teit has already prepared an extensive study on these face and body paintings. The positive taboos are those resulting from an order of the cna'ᵃm to eat certain parts of animals in specified circumstances; for instance, a man whose chief individual totem was the Deer had to eat the raw kidneys of every deer that he killed while hunting. Other taboos are negative, in so far as they prohibit the use of some foods, vegetable, or animal. Such taboos may be changed later in life by special command of the totem. The twelve 'dream' and 'vision' songs, recorded on the phonograph and taken down as texts with translations and explanations, belong to the following categories: cna'ᵃm songs for good-luck generally, songs for twins, sweat-house, medicine and war songs. The songs for general good-luck, as recorded, are those that were learned by several novices from the Loon (a 'vision' song), the Coyote (a 'dream' song), the Grass and Wind (a 'dream' song), probably also the Prairie-Chicken and the Mountain Sheep songs, and the Black Bear Sister's and the Old Man's songs. Tetlenitsa's extensive relation of his own experiences with his cna'ᵃm—first, with the two Black Bear Sisters, second, with each of the two Black Bear Sisters individually, and last of all, with the mythical Old Man—constitute, together with his 'vision' song and a text containing the Old Man's utterances, a most interesting first hand description of a series of 'dreams' and 'visions' as accompanied by their typical concomitants. The four medicine songs and other information given by Tetlenitsa and Mr. Teit were those that as many medicine men of their acquaintance had received from their protectors, namely: the Lizard, the Wolf and the Hawk, the Ptarmigan, and the Eel and a bird. A song for twins, revealed to the parents of twins by the Grizzly-Bear, the traditional cna'ᵃm, apparently, of all the twins; a sweat-house song and

prayer; and two war songs, together with interesting information on the sweat-house and war practices and cna'ᵃm experiences, have also been taken down.

(*b*) The twelve Thompson River lyric songs recorded are miscellaneous in nature and consist of four love songs, four gambling songs, and potlatch, riding, and berry-picking songs, all of which have words.

Lillooet.

Far briefer information on the Lillooet has also been furnished, along the same lines, by Ignace Jacob, a Lillooet from Pemberton Meadows, and seven songs have been recorded.

Puberty training was described by Ignace Jacob as being the old Indian system of education, lasting from five to twenty-five years. The secluded candidates aimed at becoming hunters or medicine-men with the help of a sna'ᵃm. A few candidates only were fortunate enough, however, to secure such protection, as personal dexterity was not, it seems, the only requirement; considerations of inheritance either in the father's or mother's line being also involved. It is pointed out, as a consequence, that claiming fraudulently the encounter and protection of a fictitious sna'ᵃm, on the part of an unsuccessful candidate, was not altogether unknown. The Salmon or Trout, the Snake, the Duck, the Humming-Bird, the Thunder-Bird, the Whale, a monster (corresponding to the Sisiutl or Heitlik of the coast), a Woman, the Spear and Arrow are mentioned as sna'ᵃm, the names of which are familiar to the Lillooet. A sna'ᵃm is described as appearing in the form of a man or animal to a candidate who is asleep and dreaming, and also later, while he is actually awake, if really successful in getting it as a protector.

The sna'ᵃm songs taken down with Jacob are: a private song used in a ceremonial taking place in December, two medicine men's songs, and a Bear song for twins.

Three lyric songs with words (a Lillooet longing song, a Chilcotin gambling song, and a weeping song from the Lower Frazer) have also been added by the same informant to the collection of Salish songs now in the Victoria Memorial Museum.

ON IROQUOIS WORK, 1912.

(*A. A. Goldenweiser*)

The following summary report is based on the data collected among the Iroquois tribes at Grand River, Ontario. The periods spent in the field were: in 1911, from July 6 to August 20 and from December 22 to 31; in 1912, from January 1 to February 9, from May 20 to July 2, and from September 7 to November 12—aggregating seven months. Throughout the work most emphasis was put on social organization, but information on ceremonies, societies, and mythology gradually accumulated until now the total amount of data on the last three topics about equals that on social organization. Among my informants, by far the most thorough and versatile was Chief John A. Gibson (Seneca) who died on November 1, 1912, while our work was in progress. Among the many other informants I should single out the following: ex-Chief George Gibson (Seneca); William Sandy (Cayuga); ex-Chief Abraham Charles (Cayuga); Chief John Danford (Oneida); Chief E. G. Smith (Mohawk); ex-Chief Isaac Hill (Mohawk); Chief David Skye (Onondaga); ex-Chief Johnson Williams (Onondaga); Mrs. Mary Gibson (Cayuga); Mrs. Thomas Kee (Cayuga); Mrs. Elliott (Mohawk); and Mrs. Mary Sandy (Tutelo). The data as here presented are based exclusively on my own investigations. The vast literature of the subject has not been referred to, nor has any effort been made to enter into the discussion of differences between the older material and my own data. All of these points will be fully considered at the proper place.

The method of presentation of the material here adopted necessitated a certain amount of repetition.

Social Organization.

The Phratry:—Each of the five tribes of the confederacy is divided into clans which are grouped in two 'phatries.' These dual divisions do not, among the Iroquois, have any names, nor is there any evidence of a former existence of such names. The clans of one division or 'side' call each other 'brothers,' while the clans of the other 'side' are their 'cousins,' and vice versa. No origin myths referring to these divisions were obtained except the account contained in the Deganawida myth. Although my genealogies do not extend far enough back to bear witness to the former exogamy of the 'sides,' the frequency of intra-phratric marriages seems to be less in the older sections of the genealogies. Moreover, all of the older informants are agreed as to the ancient exogamy of the 'sides' and remember incidents falling into the period of transition when the ancient rule began to give way, presently to be superseded by another exogamous regulation, that of the clan. There can, therefore, be no reasonable doubt that in ancient times the two main divisions of an Iroquois tribe were exogamous. The functions of the sides are manifold and all-important. At games, such as the peach-stone game, or lacrosse, the 'sides' are lined up against each other. The 'brothers' and 'cousins' are similarly divided at contests such as the snow-snake game or target practice with bow and arrow. At all feasts the action as well as the spatial arrangement of the participants reveal the presence of the two 'sides.' The same is true of ceremonies of adoption, ceremonies at which 'friends' are made; night wakes, memorial ceremonies, and burial. In the latter instance, the func-

tionaries at the burial ceremonial are always selected from the 'side' opposite to the one of the deceased. At all great periodic festivals, such as the Strawberry Festival, the Green Corn Festival, etc., which are held in the ceremonial long-houses, the members of the two 'sides' are always spatially divided and face each other. A speaker represents each side and, in the course of the performance, always addresses the opposite side. At the preliminary meetings of officials which always precede the festivals, two men are usually appointed to go from house to house and solicit contributions to the feast; these men always represent the 'brothers' and 'cousins' respectively. The Death Feast Society and the tribal Medicine Societies, the so-called 'Little Water' or 'Real Life' societies, follow in their performance, the phratric division. The same seems to be true of the performances of the other medicinal societies, the False-faces, Otters, Buffaloes, etc. At the election of chiefs the 'sides' are functionally represented, a point to be presently referred to more specifically. At name-giving ceremonies, the name is bestowed by the 'side' opposite to the one to which the recipient of the name belongs. In the dream-guessing ritual the guesser must belong to the 'side' opposite to that of the dreamer.

At councils, on the other hand, that is, at all meetings of an administrative or judicial character, a tripartite arrangement takes the place of the dual division. (See section on 'The Clan').

The Clan:—We now pass to the consideration of the social units embraced in the phratry, the clans. The number of clans in an Iroquois tribe is not always the same; the Seneca, Cayuga, and Onondaga have now (at Grand river) and seem to have had for some time past more than eight clans each, while the precise number of clans is different for each tribe. To the Mohawk and Oneida we shall return presently. Not every clan is represented by a chief in the Confederacy. One informant states that the arrangement of clans into phratries differed before and after the formation of the Confederacy. While the historical reference is doubtless wrong, the statement is not without significance. The clans of the Seneca before Confederacy (B. C.) and after Confederacy (A. C.) can be represented as follows:—

B. C.

Turtle	Hawk
Bear	Deer
Wolf	Snipe
Ball	Duck
	Eel

A. C.

Turtle	Hawk
Bear	Little Snipe
Wolf	Great Snipe
(Ball)	(Duck)
	(Eel)

Of the latter list, the Duck, Eel, and Ball clans were never represented by chiefs in the Confederacy. No individuals belonging to the Eel or Duck clans can at present be found among the Grand River Seneca. As stated before, the arrangement of the clans at councils did not follow phratry lines. The Seneca chiefs, for instance, when in council, were grouped as follows:—

Group I ('in control')

1 Turtle Chief
1 Little Snipe Chief

Group II	Group III
1 Turtle Chief 1 Bear Chief 1 Wolf Chief	1 Hawk Chief 1 Little Snipe Chief 1 Great Snipe Chief.

For purposes of discussion there was a further subdivision. The Turtle chief (II) conferred with the Hawk chief (III), the Bear (II) with the Little Snipe chief (III), the Wolf (II) with the Great Snipe chief (III); the Turtle and Little Snipe chiefs (I) had the deciding voice. This grouping of clans and phratries had its analogue in the grouping of tribes of the Confederacy. On ceremonial occasions the grouping was as follows:—

Mohawk Onondaga Seneca	Oneida Cayuga

When in council, the tribes assumed the tripartite arrangements:—

Onondaga ('in control')

Mohawk Seneca	Oneida Cayuga

The Mohawk and Oneida seem to have had only three clans each, Chief Gibson's insistence to the contrary (in the earlier part of our work) notwithstanding. These were the Turtle, Wolf, and Bear clans. However, among the Oneida of Oneida Reserve (near St. Thomas, Ont.) these three clans are each subdivided into three groups differentiated by the size or species of the eponymous animal. These minor groups, moreover, have their distinct sets of individual names and of the nine Oneida chiefs each is associated with one of the minor divisions. These facts were fully verified by genealogies. Their significance may become clearer in my further investigations.

Whether the clan systems of the Iroquois tribes are derived from a common historical source it is impossible to say. It cannot be doubted, however, that for a long period of time the clans, Wolf, Bear, etc., of one tribe were in no way associated with the corresponding clans of the other tribes. During the formation of the Confederacy and since, the intimacy of relations between clans of identical name but belonging to different tribes became very great. It always remained an equalization, however, not a fusion. And to this day each clan of each tribe must be regarded as the social unit. The practice of exogamy, it is true, has been extended to all clans of identical name; the clans of each tribe, on the other hand, have preserved their distinct sets of individual names. Owing to the disappearance of many individual names, cases where this last rule was disregarded have of late been known to occur. Whenever this happens, however, the act is freely criticized and disputes arise.

From the beginning of my investigations I was on the look-out for any beliefs or practices which might have pointed to the former existence of some special relations between the clansmen and the eponymous animal of their clan. All

inquiries in that direction, however, led to negative results. There was no prohibition on the killing or eating of the eponymous animal; no idea of descent from it was entertained; the eponymous animal was not a guardian or protector, nor was it a brother or friend of the clansman, Carved representations of clan animals certainly used to be placed over the entrance-doors of longhouses presumably associated with the particular clan; the practice of wearing carved miniature figurines of clan animals or of painting or tattooing them on the breast may have existed; vague references are also made to a former belief in the power of clansmen to hunt their eponymous animal successfully. Individual names among the five tribes of the Confederacy never refer to the clan animal or bird. The only indisputable fact about these eponymous animals is that they were eponymous. The animal names of clans, however, are by no means the terms by which they are commonly designated. For this purpose collective terms referring to some quality or habit of the eponymous creature are used, such as 'the people of dark complexion' (Bear), 'the people with small hoofs' (Deer), etc. Only on those occasions when the clan membership of an individual must be specifically indicated, for instance at condolence ceremonies, are the animal names used. In a description of the social organization of the Seneca, recorded in Seneca text, in which the arrangement of clans, etc., is systematically discussed, the clans are not once referred to by their animal names. The distinctive traits of an Iroquois clan may be summarized as follows: (1) the clans are exogamous (as this trait became extended so as to embrace the clans of identical name in all tribes, the clan in each tribe can no longer be regarded as an exogamous unit); (2) each clan has its own set of individual names; (3) the majority, although not all, clans claim a chief in the confederate body and participate in his election; (4) in ancient times a clan certainly owned a burial ground and possibly communal lands; (5) in ancient times clans may have been associated with longhouses, although probably not in the sense of one clan occupying or predominating in, only one longhouse; (6) in ancient times clans may have been associated with villages; (7) a clan has the right to adopt an outsider into the clan; (8) although the clans as such do not figure at ceremonies, they elect their own ceremonial officials.

No separate clan origin myths were found. When questioned on that topic, the Iroquois invariably refer to the Deganawida myth. I have recorded this myth in Onondaga text (525 pp.).

It must be noted as possibly significant that in the myths so far recorded no mention is made of clans and chiefs; instead, villages and headmen are always spoken of.

The Family:—Under this heading two distinct units in Iroquois sociology must be considered. On the one hand a family was constituted by one's relatives on the father's and the mother's side. This group was united by the ties of the classificatory system of relationship; one's father's brothers, for instance, were one's fathers just as one's mother's sisters were one's mothers, etc. The group also figured in a number of family ceremonies, and was important in connexion with marriages; it was also appealed to by the individual in numerous matters of personal behaviour, such as assuming a second name, or joining a society, or starting an important undertaking. Of far greater significance, however, was the group we may designate as maternal family. It embraced the male and female descendants of a woman, the descendants of her female descendants, and so on. The entire group was thus united by the ties of blood on the female side. The woman who at any time stood at the head of such a group wielded most powerful influence over its members. Moreover, the group as such had certain religious and ceremonial prerogatives. These functions of the maternal family have now become obsolete, and my material to date throws but little light on the old condition. In my subsequent studies I shall make a systematic attempt to

penetrate more deeply into the nature and significance of this social grouping. The genealogies indicate that whereas the chiefs are identified with clans, the actual succession follows the maternal family. The same is true of the ceremonial officials, of whom each clan has three male and three female. To a limited extent this also applies to individual names, which show a certain tendency to be passed down in the maternal family, commonly by skipping one generation. In the study of these characteristics of the maternal family, the genealogies proved a most useful tool. All in all, my genealogies now comprise over twenty-five hundred individuals and about half as many marriages. One genealogy of 258 individuals was tested as a means of systematizing the informant's data, a set of questions being asked about each individual. The results, both in quantity and quality of the information obtained, indicated that wherever genealogies can be obtained they should be used for that specific purpose. All questions where descent was involved as well as such phenomena as the gradual disintegration of the exogamous system, were tested by means of the genealogies.

The Raising of Chiefs and the Functions of Women:—The judicial and executive powers of the Iroquois Confederacy were vested in a body of fifty chiefs. Of these nine came from the Mohawk, nine from the Oneida, fourteen from the Onondaga, ten from the Cayuga, and eight from the Seneca. These chiefs must be strictly distinguished from the warrior chiefs who were elected whenever occasion required, whose office was not hereditary, and whose powers expired with the termination of the raid or other military undertaking which had brought them into being. In the case of the fifty civil chiefs the elective and hereditary principles were curiously combined. Every chief was associated with a clan—although not every clan was represented by a chief; but the hereditary right to elect a chief belonged to a smaller unit, the maternal family (q. v.), or a body of persons united by the ties of consanguinity. Small genealogies collected with this special point in view, show clearly the extent of the elective principle within these small social bodies. There seems to have been no age limit to the office of a chief; but an aged chief feeling his powers waning, would of his own accord resign, leaving his place free to be filled by a younger man. When a man was made chief, he laid aside his individual name and assumed a chief's name, which was his while he continued to be chief and then passed on to his successor, and so on *ad infinitum.* Every chief's name had a definite place in the set of chiefs' names, and at condolence ceremonies, when the names were recited, the fixed order was strictly adhered to. The differences of rank probably once associated with these names cannot now be clearly discerned, except in the case of a few names.

When a chief died, the women of his tribe and clan held a meeting at which a candidate for the vacant place was decided upon. A woman delegate carried the news to the chiefs of the clans which belonged to the 'side' of the deceased chief's clan. They had the power to veto the selection, in which case another women's meeting was called and another candidate was selected. Usually, however, the first choice of the women was confirmed by the chiefs of their own 'side' and then by the chiefs of the opposite 'side'. Thereupon the candidacy was carried to the Confederate Council to be ratified, first by the Confederate phratry of the deceased, then by the opposite phratry (see section on 'Clan'). This was followed by a public condolence ceremony in the course of which the chief was formally 'raised,' instructed in the rights and duties of his office, and adorned with the horns of the deer, the symbol of his high station. The condolence ceremony is fully described in the Deganawida myth.

The participation of the women in the procedure did not end there. The woman delegate, the same who had carried the announcement of the candidate to the chiefs, had to keep close watch over the ways and actions of the young chief. If he displayed an inclination to deviate from the accepted code of behaviour,

the woman delegate appeared before him and tried to persuade him to desist from his evil practices. If after a time she discovered that her appeal had no effect, she repeated the visit. If that also proved of no avail, she was joined by a warrior chief of her clan, and together they made a last attempt to induce the chief to reform. If their efforts proved unsuccessful, the woman delegate called a meeting of the women of her clan and publicly denounced the chief. The impeachment then passed through the various bodies referred to before, up to the final ratification by the Confederate Council. Thereupon the chief was formally deposed, and his place was declared vacant.

The prominent part played by women in the election and deposition of chiefs marks her high social status among the Iroquois. Of the six ceremonial officials who were hereditary in each clan, three were men and three women. The preparation and conduct of almost all ceremonies were in the hands of these officials. Some of the most important ceremonial societies, such as the Dark Dance and the Death Feast societies, were not only run by the women but the latter also constituted the larger part of the membership in these societies. Although women had no formally recognized voice at councils, nor ever appeared, so far as known, as appointed speakers at ceremonies, speeches were often made by women in council as well as on ceremonial occasions. Some women, a few within the memory of men now living, were reputed as skilful orators and must have wielded strong personal influence. Woman was pre-eminently the owner of property. Whereas the husband, in ancient times, could regard as his own only his weapons, tools, and wearing apparel, his wife owned the objects of the household, the house itself, and the land[1]. The children who, of course, followed the mother's clan, belonged to her. The individual names, in each clan, were also regarded as belonging to the women. In the arrangement of marriages woman was the determining factor. Not, indeed, the bride, but her mother, together with the mother of the bridegroom. The two women had full power to arrange the match, and the wisdom of their decision was seldom questioned. The oldest woman of the clan, or the woman most respected for her wisdom and experience, was a most powerful factor in the affairs of the clan, and none, not even the chief, could with impunity disregard her advice. Nor did her influence end there, for she also exercised authority over the children of her clansmen, who (the children) belonged to many clans and widely scattered districts. Thus the entire social structure of the Iroquois was permeated by a maze of channels through which keen-witted women guided the affairs of the people.

Individual Names:—The Indian names of individuals are rapidly falling into disuse, and the younger people seldom remember more than a few. A persistent attempt was, therefore, made to record all individual names stored in the memories of the older men and women. The results were gratifying. All told, some two thousand names, male and female, were recorded. They represent the Oneida, Seneca, Cayuga, and Onondaga tribes. The Mohawk set is well below fifty, the Tuscarora set still smaller, but there are grounds for believing that these sets also will be considerably extended after further work at Grand River as well as at Caughnawaga. These names were not used as forms of address. They never figured in direct address, but when one spoke about a person, the name was sometimes used, in those cases namely when the meaning was not sufficiently clear from the context of the sentence. Although the individual names were a clan characteristic, the genealogies reveal some tendency to bestow upon a child the name of a dead relative. The name was given at birth; in many cases, in fact, it was decided upon before the birth of the child. The mother herself may decide upon the name, or an older member of the family, usually

[1] In so far as the relation between individual and communal property among the Iroquois is not fully understood, the above statements must stand subject to correction.

the grandmother, or also the grandfather. In recent times, perhaps due to the fact that the names are no longer a matter of common knowledge, it became customary for the parents, after the birth of a child, to consult one of those men or women who are known as the 'keepers' of the names, and whose knowledge of names that are in use and of others that are 'free' remains quite extensive to this day. John Gibson, the Seneca chief, was such a keeper, and from him I secured an elaborate list of Seneca names (over three hundred), including names that were 'free', a few of which were subsequently bestowed upon children born since the list was written out. Although a name is thus associated with a child from its birth, it is officially and ceremonially confirmed on two fixed occasions, on the second day of the Green Corn Festival or on the second or third days of the Mid-winter Festival. The name-giving ritual has been recorded in Onondaga text with English translation. Later in life, often at puberty, the first name may be set aside and another name assumed. This procedure also takes place on the two occasions specified above and consists of a somewhat different ritual.

Theoretically no two persons of a clan should at any time bear the same name. Formerly this rule was no doubt strictly observed; at present, however, owing to the depletion of names, the ancient usage has given way, and cases where two or more persons of a clan bear the same name are not uncommon.

In content, the names have nothing whatsoever to do with the eponymous animal of the clan. Animal names, although very rare, are occasionally given, but here again they may or may not correspond to the clan eponym. Moreover, in the few instances where such names were found, they were, excepting in one or two cases, of demonstrably late origin, nor were they regarded in the same light as the regular individual names: after the death of the particular person, the animal name was not included in the set of hereditary names of the clan, but could be used by any individual of any clan. The content of the names refers to the powers and phenomena of nature, the sun, moon, thunder, night, day, etc.; occupations in the house and field; social and ceremonial functions; features of the landscape; etc. The idea of duality is often expressed in a name.

In addition to these Iroquois names, a set of English names was secured which had become transformed, sometimes beyond recognition, by the requirements of Iroquois phonetics.

Puberty Customs:—The information that can still be secured on these customs in ancient times is exceedingly fragmentary. Enough data from many independent sources have, however, been secured to indicate the main characteristics of the old usages. When a boy's voice began to change he retired into a secluded shanty in the forest; there he stayed for one year, eating sparingly, and seeing no one except an old man or woman (sometimes a relative) who took care of him. Every morning the lad had to scarify his shins with a stone; he was also supposed to run a good deal, to bathe in ice-cold water, to swim until exhausted, etc. In an Oneida version, three shanties were built in the forest (near Oneidatown, St. Thomas) for the lads at puberty, each clan having a shanty of its own. There the lads stayed with an old man for a year and were subjected to various tests of endurance. Exemplary behaviour during this period was of vast importance for a boy's future position and success in life.

There seems to have been no corresponding extended period of seclusion for girls at the time of the first mensae. She retired to a shanty only for the time she was afflicted. She was not permitted to eat hot food, and a large number of foods were tabooed to her. She was made to execute hard tasks such as chopping hard wood with a dull axe, etc. These tasks often extended beyond the period of her seclusion. If the girl during her isolation in the shanty had any dreams, they would come true.

While there can be no doubt that guardian spirits were obtained among the ancient Iroquois, the data so far secured on this topic are very unsatisfactory.

The Relationship System:—The classificatory principle has been applied with great rigour in the Iroquois system of relationship, which is, therefore, characterized by its simplicity. Blood relatives are grouped, from the point of view of *ego* into five generations: the generation of *ego* (I), the first ascending generation (II), the second ascending generation (III), the first descending generation (IV), and the second descending generation (V). The main characteristics of the system are as follows: within each generation the classificatory principle is strongly marked; distinct terms of relationship do not extend beyond the second ascending and the second descending generations; a distinction is made between older and younger brothers and sisters. Thus, in generation II the term 'father' is applied to one's own father, to the father's mother's sister's son, to the father's father's brother's son, etc. Similarly, the term 'mother' is applied to one's own mother, to the mother's mother's sister's daughter, to the mother's father's brother's daughter, etc. The term 'aunt' applies to one's father's own sister (although here 'mother' may also be used), to the father's mother's sister's daughter, to the father's father's brother's daughter, etc. The term 'uncle' applies to one's mother's brother, to the mother's mother's sister's son, to the mother's father's brother's son, etc. The III generation embraces the fathers and mothers of the individuals of generation II. To them the terms 'grandfather' and 'grandmother' are applied. These terms also cover all individuals, in the direct line of descent, of all higher ascending generations. In generation I the terms 'brother' and 'sister' are applied to one's own brothers and sisters, to one's mother's sister's sons and daughters, to one's father's brothers' sons and daughters, etc. The term 'cousin' (male and female) is applied to one's mother's brother's sons and daughters and to one's father's sister's sons and daughters. In generation IV the terms 'son' and 'daughter' are applied to one's own sons and daughters, to one's sister's (own and collateral) sons and daughters (*ego* being female) or to one's brother's (own and collateral) sons and daughters (*ego* being male), while the terms 'nephew' and 'niece' are applied to one's brother's (own and collateral) sons and daughters (*ego* being female) or to one's sister's (own and collateral) sons and daughters (*ego* being male). Generation V embraces the sons and daughters of all individuals in generation IV. To them the terms 'grandson' and 'granddaughter' are applied. These terms are also applied to all the individuals (in the direct line of descent) of the lower descending generations. In generation I separate terms are used for older and younger brother, and for older and younger sister. I shall not here refer to the terms applied to relatives by marriage. All of these terms were tested on genealogies which revealed various extensions of the terms and served to clarify shades of meaning attached to individual terms.

Ceremonies.

In every clan we find three male and three female officials whose duty it is to plan and superintend the ceremonial performances. Of these the most conspicuous are the periodic harvesting festivals. When early in spring the strawberries begin to ripen, the Strawberry Festival is held, an outline description of which I secured. In the course of the performance the motions gone through by the berry-pickers are imitated by the dancers. Similar festivities occur when the beans and raspberries are ripe. The Raspberry Festival I recorded in outline; while the Bean Festival was taken down in Onondaga text (in part translated). The ripening of corn becomes the occasion for an important four-day ceremony, the Green Corn Festival. Of this a fairly detailed, although not complete, description is in my hands. The most important periodic ceremonial of the year,

is the Mid-winter Festival which lasts five days and is followed by a period of another two or three days during which games are played. Of this ritual I have an outline description, and part of it is recorded in Onondaga text. The sequence of events in the above series of festivals may be summarized as follows. About the time when a festival is usually held, the officials meet and deliberate as to the main features of the forthcoming feast. Then two men are sent out who go from house to house and collect contributions in victuals and, in modern times, money. A second meeting of officials is called at which the contributions are examined. If the amount is sufficient, a date for the feast is fixed upon. If the contributions are scanty, the two men are sent out for another round; then the date is fixed at a third meeting. The festival opens with the selection of two speakers who are appointed by the officials. Then follows an appeal to the Great Spirit and a thanksgiving address to the powers of Nature, in particular to the three sisters, Corn, Bean, and Squash. This address is repeated in practically the same form at all of the above festivals. Next in order are songs and dances for men, for women, or for both, accompanied by rattles or tomtoms handled by men especially appointed for that purpose at each feast. During the period of the dances, which in the Green Corn and Mid-winter Festivals occupy from two to three days, the religious societies also hold their performances. On the second day of the Green Corn and on the second or third days of the Mid-winter Festivals, babies are brought in by their mothers, and names are officially bestowed upon them. Dream-guessing is a special feature of the mid-winter rituals. Persons who had dreams announce that fact to the chiefs, and the dreams are guessed by persons of the opposite 'side' in the course of the feast. The one who guesses the dream must make for the dreamer a miniature object, a canoe, rattle, lacrosse stick, etc., around which the dream centres. The object is kept by the dreamer and is supposed to bring luck and ward off disease. In the morning of the fifth day of the Mid-winter Festival the Sacrifice of the White Dog takes place. I have witnessed and recorded the rite. The significance of the entire performance is, however, by no means clear to me. It is to be hoped that further intensive study of the ceremonies, a study which may extend over two or three years, will throw light on this somewhat puzzling ritual.

As regards other ritualistic performances, brief descriptions were secured of: (1) wakes; (2) memorial feasts; (3) death feasts, in the family and the tribe; (4) adoption ceremonies, of an individual or a group of individuals, in the family, clan, and Confederacy; (5) ceremonies at which 'friends' are made. A full description of the condolence rituals is contained in the Deganawida myth. Some of the so-called 'societies' also hold ceremonial meetings, in particular the Death Feast Society and the Medicine Societies, into the Onondaga branch of which I was initiated, having previously been adopted into the Seneca tribe and the Wolf clan.

Societies.

The societies of the Iroquois, whatever their history may have been, are at the present time medicinal in their functions. The society in each tribe which is most influential and sacred is the so-called Medicine Society referred to in the section on 'Ceremonies' (q. v.). Ritualistically it falls into two divisions, of which the 'Little Water' or 'Real Life' division is by far the more secret in its performances and powerful in its social bearings. The only way of joining this division of the society is by having a dream of a certain fixed type. The other division may be joined by any one who has met with an accident, had some bone broken, and was cured by the members of the society. The other societies are known as the False-face (or Corn Husk), the Otter, Bear, Buffalo, and Eagle societies. The Dark Dance and the Death Feast societies comprise a much more

elaborate ritual than the other societies, excepting the 'Real Life', and stand in a group by themselves. All of these societies are in full swing at the Grand River Reserve as well as among the Seneca of New York State (as revealed by Mr. A. C. Parker's data). There can, therefore, be no doubt that prolonged research will result in a much fuller body of information than has so far been obtained.

Membership in a society is secured in one of a limited number of ways. A man (or woman) may fall sick and dream of an otter or buffalo; he (or she) then calls in the corresponding society, who perform their rites, whereupon the patient finds himself cured. He (or she) then joins the society and thenceforth invites its members to a feast at certain indefinite intervals, usually about once a year. There may be sickness, but no dream. Then the parents of the patient, or an old relative or a 'prophet,' are consulted. These 'prophets' are men or women well versed in the traditional magical lore. They tell dreams, practice divinations, and in an inconspicuous way continue to wield a rather powerful influence among the modern Iroquois. Following the advice of the parent, relative, or prophet, the patient appeals to a society for a cure, and if their efforts prove successful, which is usually the case (for the time being, at any rate), he or she joins the society. Unless this is accompanied by the periodic festivities referred to above, the society takes revenge and the patient may again become afflicted. Some societies are appealed to as specialists in certain diseases. The False-faces, for example, are particularly efficacious in cases of swelling of the face, tooth-ache, inflammation of the eyes, nose-bleeding, sore chin, and ear-ache. One woman dreamed that she was crossing a river over an ice-bridge. The bridge gave way and she found herself afloat on a chunk of ice which continued to revolve, intermittently plunging her into the water and then bringing her to the surface again. She awoke and, after consultation with a prophet, became a member of the Otter society, which is intimately associated with water. Another woman joined the same society after dreaming that an otter carried her across a stream in a miniature canoe which the otter held in its mouth. One man, a skilled false-face carver, when he was a young boy, used to amuse himself by carving small false-faces. His parents objected to the practice and put a stop to it. About two months later the boy fell sick. Then his parents advised him to join the False-faces. He was cured by them and became a member of the society. Some three years ago an Oneida man of powerful frame and great strength, suddenly became ill. He could not locate the source of his trouble but felt his strength waning from day to day. His weight was rapidly decreasing. While he was thus afflicted, it so happened that he was travelling alone through the woods. Suddenly he heard a strange whistle which he readily identified as the voice of the False-face. Being of a skeptical disposition, he did not pay much heed to the incident, and reached home. Meanwhile his illness grew worse, and twice the False-face appeared to him in a dream, and spoke to him. Then he resolved to call in the False-faces. They performed their rites, and presently he felt relieved. Of course, he joined the society. (This personal experience is recorded in Oneida text.)

In addition to their activities as visiting physicians, some of the societies practice ceremonial rites or exercise medicinal functions of a more generalized kind. The Medicine Societies hold elaborate ceremonial meetings (see section on 'Ceremonies'). The False-faces, twice a year, in spring and in autumn, separate into two bands. The members of each band, wearing false-faces, rattles in hand, and garbed in appropriate costume, go from house to house and amidst singing and rattling of the turtle shells, drive away the disease spirits. Then the two bands reunite, and a ceremonial meeting is held at the tribal Long House.

I have recorded the origin-myths of the following societies: the False-faces (Onondaga text with English translation); the Buffalo Society (English); the Dark Dance and the Death Feast societies (English).

Mythology.

The mythological material so far secured is not large and curiously uniform. The prevailing type of myth is an epic account of the wanderings and achievements of a pure young man, often an orphan, who is an expert runner and hunter. Possessed by a desire to find out where the dead people go to or simply seized by a Wanderlust, he starts out alone, or accompanied by his bride, for the forest, hunts as he goes on, secures the friendship of the wild animals by sharing with them the produce of his chase, has encounters with Stone-giants, or Pygmies, or the False-face, obtains from them, often in exchange for some power of his own, various magical objects, incidentally witnesses the performance of the Death Feast or Dark Dance or a lacrosse game (which he subsequently introduces among his people), safely returns to his village, and henceforth becomes an influential man owing to his knowledge and powers. In these myths a day is always equal to a year, and animals always appear in the shape of men. In one myth, for example, an Indian stranded in an unknown country wanders on through the forest. Every night he addresses the wild animals and leaves for them the larger part of the produce of his chase; the animals, in return, protect him; he meets the False-face, visits the False-face village; presents them with twelve bowls and twelve bows and arrows of his own making. In return they promise to appear to him in dreams and warn him of dangers. Later he meets the Stone-giant, narrowly escapes death from his terrible voice, is pursued by the giant, but finally turns on his pursuer and cuts him to pieces with the giant's own axe. From the giant he obtains a magic skin which gives him power over all the animals, and a stone finger which, in falling, indicates a desired direction. The Indian returns to his village and, being warned by the False-faces of the approaching enemy, organizes a war-party, falls on his foes and exterminates them.

In addition to this, the following mythological accounts were recorded: the Deganawida myth (Onondaga text); the story of the Indian who scalped a chief who had insulted him; the traditional account of how Chief Danford's great-grandfather joined the False-face Society (Oneida text); the Origin of the False-faces (English and Onondaga text, incomplete owing to the death of Chief John Gibson, the informant); the Girl at Niagara Falls and the Snake (English); the story of the Dead People (English; Origin myth of the Death Feast Society); Origin myth of the Seneca clans and phratries (English; a version of part of the Deganawida myth); the Division of the Snipe Clan (English); story of the Young Brave who met a Serpent (woman) and saved his people from destruction (English); the story of 'Flier,' the great runner (Seneca text); the story of the Good Young Man and the Girl who gave him corn (Onondaga text and English); story of the Magical twins (English); an imperfect Onondaga version of the Cosmogonic myth; the Pygmy Myth (English; origin myth of the Dark Dance Society); and few relatively brief myths referred to before.

Material Culture.

In view of the fact that a complete survey of Iroquois material culture is being made by Mr. F. W. Waugh, of Toronto, I have devoted relatively little time to that subject. Fairly detailed information was secured about the carving of false-faces. I have witnessed and recorded the process of carving. The false-faces are of considerable interest from the artistic point of view. While the range of variability of the false-face forms is fairly wide, there exists a definable limit to such variations. Preliminary notes were taken on the different styles of false-faces as well as on the significance of special features and of the different colours used. These data may serve as foundation to a more elaborate study

of the false-face technique and styles from the artistic point of view. Considerable material was secured bearing on the construction of the ancient bark-house, as well as of the several types of shanties and the later log-house. A peculiar type of fire-place and chimney used in the bark-house, and later in the log-house, were circumstantially described by two independent informants. I also recorded in Oneida text a complete description of the erection of a bark-house, including the felling of trees, peeling of the bark, the preparation of the bark, the clearing of the ground, the erection of the frame, the method of attaching the bark, etc. The process by which a long-house develops out of an ordinary dwelling house, was inquired into with particular care. According to my information, at least two methods must have been used for that purpose. An average family of seven or eight individuals would live in a regular 'dwelling' house with one fire-place and one smoke-hole. As the family increased, by the births of children and through marriages, the house would become too small for comfort and another house would be built adjoining it. In consequence, one of the shorter sides of the original house would either be torn down so that the two houses would actually form one longer house, or the second house would be built so closely to the first that one could pass directly from one to the other. The resulting structure would be a small long-house with two fire-places and two smoke-holes. The process continued until a large long-house with seven, eight, or even more fire-places had developed. When further increase in the population began to tax the capacity of the long-house, a new house was erected, parallel to the first; in the erection of that house the inmates of the long-house were assisted by their relatives.

In conclusion, I want to add that the death of John Gibson, my main informant, necessitates a radical change in the method of my Iroquois work. Whereas in the course of the work to date, it was possible, in fact imperative, to spend about one-half of the time in systematic study with Gibson, whose information on social organization, societies, ceremonies, mythology, was equally vast and reliable, no such concentration of work will henceforth be possible, nor will it be wise to longer delay the extension of the field of operation, so as to include at least the conservative Seneca of New York State.

ON WORK IN MATERIAL CULTURE OF THE IROQUOIS, 1912.

(*F. W. Waugh*)

Some six weeks or so were spent in January and February of 1912 in making a broad beginning in the subject of Iroquois material culture, in the fullest possible interpretation of the word. This succeeded a brief period spent upon the Grand River reserve in the summer of 1911, in which a general survey of the field was obtained and a few field notes made in various departments. A number of photographs were also obtained at this time.

The period first referred to was spent entirely upon the Six Nation Reserve in Brant county and included as many subjects as could be handled adequately in the time. A third visit of three months or more, beginning with April 8, was paid to the same reservation. The remainder of the seven months, which were devoted during this season to the study of Iroquois material culture, was divided among the reservations at Tonawanda and Onondaga Castle, New York; Caughnawaga, Quebec, and Oneidatown, Ontario. The following were among the subjects investigated:—

(1). Food materials and preparation, in which a beginning was made in the collection of specimens of the materials used, including corn, beans, squashes, gourds, etc., with special reference to native aboriginal foods. These were found to include mammals, birds, fish, batrachians, reptiles, crustaceans, molluscs, and insects. The vegetable foods also included cereals, nuts, and fruits generally; the roots, stems, flowers, and leaves of plants; various products derived from trees; lastly, the orders of the fungi and thallophyta. A considerable mass of material was collected on this subject.

(2). Basketry, a craft which seems to have received a marked impetus in certain directions in response to the white demand, and which is now disappearing rapidly because of the general use of factory-made baskets and the increasing scarcity of the black ash, the material most largely employed. Special attention was given here to styles of baskets employed for home use, or in native industries and employments. It was found, too, that other materials than the ash have been made use of from time to time, and specimens illustrating the use of some of these were obtained. A series of photographs showing the principal steps in basket-making was made.

(3). Transportation, including all devices employed in carrying goods from place to place, or in travelling. There is a marked scarcity of anything to illustrate this at present, with the exception of an occasional pack-basket and strap, a few dug-out canoes, and here and there a sleigh for hauling loads by hand. Not more than two or three types of pack-basket were noted, but specimens of four different types of carrying-frame were obtained, together with models of some five or six different types of sleigh.

Snowshoes are no longer used, except in eastern Ontario and Quebec. Specimens of two old types of these, however, were made by one of the older men at Grand River reserve. Moccasins, also, are seldom used, although a few are still made at Caughnawaga and St. Regis. The baby-board, which might also be mentioned as a carrying device, has practically disappeared. except at one or two points in eastern Ontario. Some information was also gathered on the cognate subject of bridges and bridge-building.

(4). House-building can hardly be called a native industry as practised at present. Modern methods have been adopted everywhere. Even the log-house, the oldest type to be found, is essentially white in design and construction,

with perhaps an occasional aboriginal modification. It was found possible, however, to get descriptions of various types of native bark houses from some of the older men, a number of whom claim to have assisted in their construction. Descriptions of the interior arrangements, and furnishings, the construction of chimneys, fireplaces, beds, etc., were obtained in the same way, also a description of ancient fire-making and lighting devices, with specimens of these. Regarding the still more ancient arrangement of the houses into villages, stockaded or otherwise, practically nothing is now remembered.

(5). Silversmithing seems to have been about the last of the metal-working crafts among the Iroquois, although these were probably never of much importance and consisted principally in the working up of stray bits of native copper, and, at a later date, of scraps of material obtained from the whites. Silversmithing, moreover, as has been shown by A. C. Parker and others, is evidently an adoption of a European handicraft, including both the tools and the designs employed.

At the present time, there are probably not more than three or four Iroquois, either in Canada or the United States, who know anything about silversmithing, and these have practically discontinued the art. Even the kits of tools employed and handed down, in some cases, from one worker to his successor, have been purchased by some of the museums. A couple of workers had purchased new outfits and from these an idea was obtained of the methods used. A few silver ornaments of various kinds were obtained, but many of the designs are no longer to be found.

(6). Mat-making from the husks of the maize or Indian corn gives employment to some of the women, and illustrates an interesting use of a by-product, also the adaptation to modern uses of what is claimed to be an old-time household article.

(7). Tanning was investigated from time to time. It is rarely practised now, but descriptions in detail were taken from a number of old men. Reproductions were made of the principal implements and tools employed, and later on, some of the more important processes were illustrated practically by various informants.

The process, as noted, consists of the soft tanning of large hides, such as those of the deer, with or without the hair; the preparation of rawhide for lacrosse and snowshoe lacings, etc.; and the tanning of furs.

(8). Textiles of native manufacture were found to be very scarce indeed, and probably were never made to any large extent among the Iroquois. At the present time the only articles representative of this department are a few burden straps or 'tump lines', and, in certain localities, a few woollen sashes woven by hand. Specimens of both of these were obtained. The raw material for this class of work was found in plenty and included a variety of vegetable fibres of very good quality, both as to appearance and durability.

(9). The dyes formerly used in colouring splints and other materials for basketry, also for textiles, wood, bone, and for application to the body or face, were found to be rapidly passing into disuse, but, by making inquiries of many individuals, a considerable number of methods were obtained. Many of these were productive of excellent results.

Colour nomenclature was given particular attention in this connexion and, although there is no doubt that much still remains to be done in this direction, more especially by workers in linguistics, some very interesting notes were obtained.

(10). Art among the Iroquois is not developed to any great extent, and seems to have suffered rather severely from modern influences. An intensive study of the subject seems to indicate that utility was uppermost in the economy

of the Iroquois, though much artistic taste in form and decorative design is discernible.

Many of the older materials have either disappeared entirely, or are used to a limited extent locally. All, in fact, have been more or less subjected to change. Beads, for instance, have practically displaced such decorative materials as porcupine quills, moose hair, etc., and even beadwork is rapidly falling into disuse, though a few excellent examples were collected from some of the reserves.

Iroquois art, as it exists today, may be classed under the headings of decorations in relief and those applied to flat surfaces. Very slight use is made of paints or dyes at present, except in basketry and one or two minor articles of use, and in spite of a popular belief to the contrary, considerable taste is shown in the selection and combination of colours. Natural floral motifs or patterns are used quite abundantly in beadwork and applied decoration generally. There are also some very good conventional floral and geometrical designs. The carving and relief decoration found is usually rather rude, but sometimes shows considerable excellence and includes bird, mammal, human, and other forms. This is employed principally in connexion with articles of wood. Much general artistic taste, also, is shown in the matter of woodworking, basketry, and other handicrafts.

(11). Traps and trapping furnished an interesting field of inquiry. Modern contrivances have taken the place almost completely of the older woodcraft, but the transition was evidently not so long ago but that some were still able to give an explanation of the older methods, and to construct models illustrating these. A couple of models of traps for small mammals were obtained in the winter, also a full-sized fish-trap as still used in some localities. During the summer, models of over a dozen traps for birds and mammals were secured. The informant in one instance was a man of not more than fifty years of age, who possessed a most valuable fund of knowledge regarding woodcraft of all kinds. A considerable amount of most interesting information on the subject of fishing and hunting medicines and formulæ was obtained from the same informant, also medicines used to secure success in games and sports. This information was added to extensively by informants at the other points visited, where additional models of traps were also secured.

Other methods of catching eels and fish than by the use of the trap were found to have been practised within the recollection of informants on the reservations visited. These included such methods as spearing, and dragging or driving. Examples were obtained of several types of spear.

(12). Games, whether household, ceremonial, or athletic, were given due attention. A number of these are practically obsolete, though a considerable number are still current. Much insight into Iroquois character may be gained from a study of these. Their athletic games, for instance, give scope for the highest development of both muscle and skill. There are several which are tests in precision in throwing or projecting weapons, some are tests of mental perspicuity, others show a leaning to the grotesque or humorous. Adaptations of European ideas were occasionally found.

Toys might also be mentioned in connexion with games. There were found to be comparatively few of these of strictly native conception. A few were found, however, as well as the usual adaptations.

(13). Weapons, as used at the period of discovery, or earlier, have doubtless been subjected to much change. The examples obtainable at present are few in number and have been retained for special occasions rather than for use. Other weapons and accessories have disappeared entirely.

The bow, formerly used with much skill, remains as an article for holiday use, or more rarely for demonstrations of marksmanship, or for hunting small game. Several more or less distinctly marked types of these were secured for

the museum. Of the tomahawk, some four or five types were collected. The 'hoop and javelin' game and the throwing-stick, both seldom used now, seem to be among the last remaining representatives of the spear or javelin type of weapon. Specimens were also obtained of these.

(14). Medicine in all its branches was gone into as thoroughly as time would permit. This was evidently a very extensive subject, and although some twenty-one or two good medical informants were secured and hundreds of medical prescriptions and formulæ recorded, it cannot be said that the subject was in any sense exhausted. This was to some extent owing to the fact that medical procedure differed slightly with the various practitioners and that hardly any two prescriptions were identical. Most heads of families were found to know anywhere from one or two to half a dozen remedies, and a great many of these were also obtained. Several different schools or categories of medicine were observed. These might be roughly classified as: (1) those making use of medical preparations only, of which the greater part are herbal; (2) those making use of divination and other supernatural agencies in the diagnosis and cure of the disease; (3) those using a combination of magic and therapeutics; (4) those practising witchcraft by means either of medicines or of supernatural agencies; also its cure. Other aspects or phases of Iroquois medicine are represented in the virtues attributed to certain mystical or traditional medicines; the functions of the various medical and secret societies; the use of fetishes and amulets to ward off disease. Informants on medical topics were selected to represent, as far as possible, the different geographical or botanical areas.

A collection was also made of Iroquois fetishes and amulets, as well as of articles used in medicine proper, and in witchcraft. Numerous invocations or prayers and other formulæ were recorded in text.

An interesting series of anatomical terms was given by several informants, one or two of these showing a surprisingly accurate knowledge of structural anatomy.

Another branch of inquiry was the investigation of old customs and the medical or surgical ideas in connexion with pregnancy, birth, puberty, and the menstrual period. The subject is one which could evidently be extended almost indefinitely, but a good foundation, we believe, has been laid, and a sufficient amount of information secured to illustrate the main features of Iroquois medicine.

(15). Musical instruments were found to be fairly numerous, though somewhat crude in type. The greater number of these consist of instruments of percussion for marking the time or rhythm in singing and dancing. The most ambitious instrument, a flute of cedar, was carefully studied as to construction.

(16). Costume was given considerable attention from time to time, both incidentally to inquiries on related topics, and as a special department of inquiry. Much white influence is to be noted here, though many interesting facts were gathered.

Some information was also secured on such subjects as hair-dressing by both men and women, shaving, paints, toilet accessories, etc.

(17). An interesting evolution is to be noted in the transition from bark utensils to those of wood. A fairly complete set of specimens illustrative of this was obtained. Where actual specimens of old-time make were not obtainable, some of the older men were set to making them.

(18). One of the minor occupations noted was the culture of Indian tobacco (Nicotiana rustica). This is raised principally for ceremonial purposes, though it is smoked by a few of the older people. Methods of planting, cultivation, and curing were recorded. Further information as to its use was included with medicine.

(19). Woodworking has evidently been a most important employment of the Iroquois, at any rate since the introduction of steel tools, which also materially improved the quality of the product. At the present time it is falling into disuse from the competition of ready-made articles.

Among the articles which illustrate the skill of the Iroquois in this direction are: canes carved in fancy designs; the handles of stirring paddles and paddles for lifting out corn bread; wooden spoon handles; the bows on baby-boards, the decoration of the latter having been an occupation quite distinct from the making of the boards; the carving of wooden false-faces, which also shows some art, though decidedly grotesque in character. In the investigation of woodworking, not only were the different steps and processes noted carefully, but also the tools, examples of which were secured where any aboriginal feature was noted.

It was noted from time to time that many interesting units of measurement were used in connexion with various handicrafts. This naturally directed attention to numerical and metrical systems in the different Iroquois dialects, which were also recorded. The Iroquois names of plants, animals, the various raw materials used, and of the different steps and processes noted were all recorded as carefully as possible.

A special effort was made to secure photographs of all important features of Iroquois material culture, so far as these are now obtainable. Among the subjects thus illustrated or recorded were: costumes, hair-dressing, basketry, silversmithing, architecture, bridges, the method of drawing the bow, the use of the throwing-stick, fish spearing, fish trapping, woodworking, food preparation and the grinding of corn, transportation, etc. Other photographs taken show typical physiognomies, medical informants, and other subjects.

ON MALECITE AND MICMAC WORK, 1912.

(W. H. Mechling)

During the months of August and September, 1912, I spent six weeks among the Malecite of New Brunswick. Practically the entire time was spent at Fredericton in work with the Indians of the St. Mary's reservation. This year my work was chiefly on mythology and folk-lore, my informant being Jim Paul. The stories collected may be divided into four divisions: stories dealing with the culture hero; stories about supernatural beings, giants, etc.; stories of a more or less legendary character about famous chiefs and warriors, and personal narratives of magic and the obtaining of power. As a result of three summers' field work I now have a fairly complete collection of Malecite mythology and folk-lore, but I regret to say that I have thus far been unable to secure the entire cycle of the culture hero.

I also made a collection of herbs, recording phonetically their Malecite names, and making notes of their use, methods of preparation, and application. I also took the opportunity to obtain data on some points of material culture which were not quite clear from my notes of last year.

My linguistic work was entirely on Micmac this year. I revised phonetically all the texts which I obtained last summer, and went over the translation in order to clear up doubtful points. I also obtained some additional myths in text, and studied some points of morphology suggested by the texts.

ON OJIBWA WORK IN SOUTHEASTERN ONTARIO, 1912.

(*P. Radin.*)

My survey of the Ojibwa Indians of southeastern Ontario extended from March 1 to September 1, 1912. The most eastern settlement visited was Rice lake and the most western Garden river, near Sault Ste. Marie. The final results consisted of a collection of mythology, and diverse ethnological items in text, aggregating about 525 pages; about 175 pages of mythology in English; about 150 pages of ethnological notes; and a similar amount of grammatical notes.

The settlements visited were the following, in the order named: Sarnia, Kettle Point, Walpole island, Rice lake, Chemung lake, Garden river, Manitoulin island (including some places on the north shore of the Northern channel of Georgian bay), North Bay, Rama, Snake and Georgina islands in Lake Simcoe, the Chippewas of the Credit, and the Chippewas of the Thames. A trip of a few days was also made to the Algonquins of Maniwaki, Que. It was unfortunately impossible to visit the Ojibwa settlements of Chippewa point, Cape Croker, Parry Sound, and those scattered between Parry point and Lake Nipissing.

In none of the places visited was the old ceremonial life of the Indians in force any longer, and for that reason it was found necessary to confine the investigation to those phases of Indian custom and belief which are still remembered to a considerable extent, namely: mythology, folklore, magic and witchcraft, and religious and general ethnological practices. What the writer obtained on these subjects is only a fragment of what can still be obtained by a longer sojourn among these people. Particularly advantageous for a more intensive study are the reserves at the Thames, and Walpole island, where a small but energetic minority of Indians are still pagan.

The results of the survey naturally fall into the following headings: the former home of the southeastern Ojibwas; their language; their mythology; their religion; and their general ethnology.

(1). *Former Habitat.*—All the Indians in the settlements visited were one in declaring that they entered Canada from the United States, and that they came from Michigan either by way of Detroit or Mackinaw straits. From this statement the Indians of Rice and Chemung lakes, and of Snake and Georgina islands must be excluded, as well as those of Rama, who claim to have come from the north. The Garden Lake Indians represent two groups, one coming from the north, the other from the United States. The correctness of these statements is borne out by the difference in the dialects of the Garden River and Rama Indians, and the other settlements, which, while it is not of a far-reaching nature, is sufficiently constant and distinct to be significant. Strangely enough, the Indians of Rice and Chemung lake, who unquestionably came from the north, speak the same dialect as the settlements of Sarnia, the Thames, etc., although one might expect them to belong to the Garden River-Rama group. These Indians, who have had a history independent of either the Garden River-Rama or Sarnia-Thames group, are generally known under the name of the Mississauga.

(2). *Language.*—The language is practically the same throughout the whole area, but besides a difference in vocabulary, which seems purely of a local nature, there is quite an interesting phonetic difference between the Sarnia-Thames and the Garden River-Rama group. The former drop all initial vowels except under certain conditions, and in rapid speech, the ordinary speech of conversation,

drop many of the vowels between consonants, thus giving rise to quite a number of pseudo-consonantal clusters. The latter do neither of these things, and in this characteristic seem to belong more to the western group of Ojibwa, whose language has been described by Baraga.

(3). *Mythology.*—The myths collected are typically Woodland and are similar to Menominee and Ojibwa collections that have been published. The Trickster Cycle, with Nenebojo as chief character, is quite prominent. Stylistically they seem to prefer the long story, but there seems to be no tendency at all toward long and unified cycles, as among the Winnebago and Iroquois.

(4). *Religion.*—Their religion is that characteristic of the Woodlands, the most important phases of which have been described by William Jones in his article on 'The Concept of the Manitou' (Journal of American Folk-Lore, vol. 18, 1905). Puberty fasting and the obtaining of a personal guardian spirit is the most prominent element of their religious beliefs. I have described the most salient characteristics of this belief among the Ojibwa in a little article, about to be published in the Museum Bulletin.

(5). *General Ethnology.*—The unit of social organization was the clan, which generally had an animal name, although two clans with plant names were found, Birch and Birch-bark. Individuals did not often have animal names, nor do these or the other personal names seem to be connected in any way with the clan animal. No taboos of the clan animal existed, although that of the guardian spirit was very strong. On the whole, the clan unit does not seem to have been very strong, and in this respect shows a marked contrast to that of the Menominee and Sauk and Fox. One exception must be made to this general statement, namely, the clan unit of the Mississauga, which appears to have been strongly influenced by their contact with the Iroquois. The Mississauga have twelve clans and a fixed set of clan names for each clan. Unfortunately only a few of these could be collected at this late date.

In former times, both the Midewiwin and Calumet dances were practised. About the latter, I could obtain no definite information, but the notes obtained about the former seem to indicate that the Midewiwin in this region consisted of a very loose ceremonial unit, and that to all intents and purposes it was little more than a more or less informal meeting of shamans.

The above investigation was undertaken as a preliminary step toward a complete survey of the many divisions of the Ojibwa.

ON TAHLTAN (ATHABASKAN) WORK, 1912.

(*J. A. Teit.*)

As a commencement of an ethnological survey of the northern Athabaskan tribes in British Columbia and Yukon territories, I made a trip to the Tahltans of Cassiar district, B. C., from August 15 to November 1. Time occupied in travelling, and unavoidable delays en route, curtailed the period of actual work among them to some forty days. Within this time, however, I made very fair progress, collecting about 450 pages of information on general ethnology, mythology, traditions, language, etc. I also collected 61 songs, and some ethnological specimens, chiefly bags, tools, etc. Certain material from the tribe had already been published, viz., 'Notes on the Indian tribes of the Northern portion of B. C.,' by Dr. G. M. Dawson (Annual Report of the Geological Survey of Canada, 1887); 'The Nah·ane and their Language,' by Father A. G. Morice (Transactions of the Canadian Institute, 1903); 'Notes on the Tahltan,' by J. A. Teit (Boas Anniversary Volume, 1906); 'Two Tahltan Traditions,' by J. A. Teit (Journal of American Folk-Lore, 1909); and 'The Tahltan Indians,' by Lieut. Emmons (University of Pennsylvania Publications, 1911). The last is a valuable contribution, and comparatively full. The information I collected on the trip covers a wider range, and on the whole is much more in detail than what has hitherto been collected. However, more remains to be done.

Linguistically the Tahltans are a part of the Nahani, an Athabaskan division occupying most of the extreme northern interior of British Columbia west and east of the Rockies, and some adjoining parts of Yukon Territory. The northern and eastern Nahani appear to be composed of a number of loosely connected and slightly organized bands, nomadic in character, and conforming in general social conditions to the average type of the northern Athabaskans. On the other hand, the western branch of them, known as the Tahltans, have the status of a distinct and independent tribe, have a strong social organization, are semi-sedentary, and differ a good deal in general culture from their congeners farther inland. They have traditions that they are of diverse origin, some of their ancestors having come from the north and south, others from the east. They also claim that there have been migrations from among them to the coast, and vice versa, and that at least part of the Tlingit are thus of Athabaskan descent. They agree that the Tlingit formerly extended farther south along the coast, and also occupied from time immemorial a considerable part of the interior north of the Tahltans, including most of the drainage basin of the Taku, and nearly all the northwestern headwaters of the Yukon, north almost to latitude 62 and east to the Pelly mountains and the height of land dividing Teslin waters from the upper Liard.

The Tahltan tribe for long has had intimate intercourse with the Tlingit, and no doubt has been powerfully influenced by them. Their social organization appears to be based largely on that obtaining among the Tlingit. Like the latter, they are divided into two exogamous phratries called Wolf and Raven (the former is said to represent the original Tahltan people). Children belong to the phratry and clan of their mother. Each phratry consists of three clans or gentes, each of which has a hereditary chief and a territory of its own. These six chiefs form the governing body of the tribe. The names of the clans are geographical, and in origin they were probably mere local divisions or bands of the tribe. The clans do not have special totems, nor traditions deriving their origin from mythological ancestors. Crests and totems usually belong to the phratry. A seventh clan exists at the present day, having originated about 150 years ago through

immigration of and intermarriage with the Tlingit. It belongs to the Wolf phratry, but has no recognized territory nor chief within the country of the Tahltans; it is called by its Tlingit name. There is an aristocracy of rank and wealth, but these nobles have no special rights in hunting grounds, fisheries, etc. Methods of obtaining rank, the potlatch, and many of the social and ceremonial customs of the tribe are clearly adopted from the Tlingit.

The Tahltans made most of their implements of bone, horn, and wood. Stone was not much utilized, excepting obsidian for arrow, spear, and knife points. Tools of serpentine, jade, and copper appear to have been obtained from the Tlingit. No matting or woven basketry was made, while bark basketry was made to a limited extent. Bags were used very extensively, and were of various kinds. Most of them were made of skin dressed with or without the hair, but some were of babiche, sinew twine, and woven or netted goat's wool twine. Robes of woven strips of rabbit skins were made.

Lodges were of the single and double lean-to types, mostly the latter. They were roofed with poles laid close together, and sometimes further covered with brush, bark, and earth or snow. No conical lodges were used, nor semi-underground dwellings. Large houses built of poles and bark were used for drying salmon, and also as dwellings during the fishing season. They were similar in shape to some of the plank houses of the Tlingit.

Probably owing to exigencies of climate, the Tahltans borrowed but little in the way of dress from the Tlingit. Their every-day dress was of the Interior and Athabaskan type. However, much of their ceremonial and dance costume was Tlingit. Porcupine quill embroidery was done on clothes and bags, and shells obtained from the Coast were much used for personal adornment and ornamentation in general.

Roots and berries were not very important items of the food supply, as among the tribes in the southern interior of British Columbia. The flesh of game animals and salmon were the all important staples. Fish were caught with traps (of several kinds), nets (formerly made almost altogether of sinew twine), and spears (generally of the single point harpoon variety); game was snared and trapped, and also hunted with bow and arrows. The latter were of Athabaskan types.

A sign language was in vogue, especially among hunters. Snow-shoes were much used, the fillings being of babiche and sinew twine. It is said that very long ago the people did not know how to make them. Dogs were not used for hauling sleds and carrying loads until recent times. Formerly they were utilized only for hunting. As the Tahltans occupied an important geographical position for trading, they engaged much in this avocation, acting as middlemen in the exchange of commodities between the coast and the tribes farther inland, making profits both ways. Wars appear to have been engaged in only with the Upper Naas people, and with the Tlingit of Taku river. Scalps were taken, and a scalp dance held, but there seems to have been no war dance preparatory to going to war.

Puberty ceremonials appear to be rather strongly developed, and on the whole are quite similar to those obtaining among the Interior Salish (particularly to the customs of the Thompson River Indians regarding girls). A whipping custom was prevalent, and is also similar to that found among the Thompson River Indians. Marriage customs seem to resemble those of the Tlingit. At least for a long time back the dead have been disposed of by burning, the charred remains being gathered up, and usually placed in a receptacle on the top of a low post.

Some of the Tahltan beliefs are very interesting. The earth is thought to be circular, and to be surrounded by salt water lakes. The sky is dome-shaped, and hangs over the earth like an umbrella, the edges touching the waters all around. The sky revolves sunwise, while the earth is considered stationary. At the edges

of the earth the weather is always chilly. Some think that above or beyond the sky there is another earth, which is inhabited by birds. Possibly the sky is the floor of this other world. There is also a belief that the earth is animated and the same as the mother of the people, while the sun is masculine and the same as their father. The sun was formerly prayed to, and traces of sun worship abound. The earth we tread is like a crust, or skin or blanket, which is held up by the earth mother, who is like a post that supports it. When she gets tired, she moves her position, which causes an earthquake. She is becoming older and weaker all the time, therefore the earth is not so high as formerly, and is sagging down into the waters. Some day she will be unable to hold it up any longer. She will fall like a rotten post, and the earth will drop down and be submerged. There is also a belief in the meat-mother, who gave birth to all the animals and still controls them. The moon and stars are transformed beings. Wind is the breath of people, viz., a cold people who live in the far north, and a warm people who live in the south. When they speak, cold and warm winds blow over the earth. Thunder is a bird, and the noise of thunder is caused by the flapping of its wings. Its armpits are red, and when these are exposed by the extending of its wings, the red is seen as lightning. The Tahltan believe in several kinds of supernatural beings, including one or two races of wild people, cannibals, giants, water people, and a kind of gigantic toad. According to some, snow and rain are made by the moon. There is a strong belief in the rebirth of souls. A deceased relative is often born again by a mother, aunt, sister, or other relative. Witchcraft is believed in, witches being a class distinct from shamans. The dead go to three different places: a rather cool, dingy place underground to the west; a light agreeable place on the same level as the earth to the east; and a place above in the sky. Only people killed in battle go to the last. Sometimes they come out, and dance as the aurora. When the latter consist of red clouds, people say there is war somewhere. When the streamers of the aurora descend, forming a kind of chute, it is said the spirits are receiving a brave warrior whose soul ascends through this chute, and is borne away as the streamers ascend. The sky heaven is said to be the best abode. That to the east is somewhat like this earth, but better in so far as food is always abundant. Most people go to it. They have to descend a slippery hill, and cross a river. Some are afraid, and turn back to be reborn again, or wander about until they finally reach the place of shades in the west, where conditions are not as good as in the other places, and food is often scarce. It is interesting to note the presence of riddles among the Tahltan, a feature that has not often been reported for North American tribes.

Although there are some striking resemblances, I found the customs and beliefs of the Tahltan to be considerably different on the whole from those obtaining among the Southern Plateau tribes (Interior Salish). I collected a considerable number of mythological tales. Most of these are short stories, the only one of considerable length being that of Big Raven. All the stories of the Raven cycle, as well as many others, appear to be of Tlingit origin. On the whole there is little analogy between the tales of the Tahltan and those of the Interior Salish. The story of the Snake Lover was told in practically the same form as among the Thompson River Indians, and a few incidents in stories were the same as, or related to, those occurring in the south. Most of the songs I collected were Tahltan, some of them said to have originated with or been composed by people of the tribe. I also obtained a series of songs belonging to the Bear Lake Sekani, which is interesting in that they differ on the whole from the Tahltan music and appear to have more melody.

I did not have time to deal extensively with the language, which has a musical cadence and is rather difficult in its phonetics. Father Morice says of it, 'Besides their accent, the Nah·ane have, when speaking, a particularly marked intonation.

This is so pronounced, it could almost be compared to a song.' Again he says, 'to sum up, the Nah·ane language is much less complicated, and verbally poorer than the Carrier. It is also less pure in its lexicon, more embarrassed in its phraseology, and, owing to its accent, even more delicate in its phonetics.' To the north, east, and southeast of the Tahltan is an immense area thinly inhabited by Athabaskan bands, the dialects, customs, beliefs, and mythology of which are very little known.

ON ESKIMO WORK, 1908–12.

(*V. Stefánsson*)

The second week of August, 1912, I landed in Seattle from a four years' scientific expedition in the Arctic regions of Canada and Alaska. Such fragmentary reports as the opportunities allowed I had from time to time been sending to the Survey; just now, without any particular reference to these, I shall attempt a short general summary of the work of the entire expedition.

The financial support of the expedition was shared by the Survey with the American Museum of Natural History in New York. It was considered possible we might find on the north coast of the American continent, in the region of Dolphin and Union straits and Coronation gulf, Eskimo who had never come in contact with white men. The study of these people, if they should be found, was to be my own province, as well as the ethnological study of any other primitive people with which the expedition might come in contact. During the summer months we expected to do such archæological work as the conditions permitted and collections of linguistic notes and folk-lore material were to be made wherever practicable. The secondary aim was the zoological study of whatever regions might be traversed for ethnological purposes. This branch of the work was under Dr. R. M. Anderson, the well known zoologist, who was my only white companion in the work. It gives me pleasure now to report that the expedition has been successful in every particular. We discovered several tribes of Eskimo who had not, neither they nor their ancestors, ever come in contact with white men, so far as they know or so far as we know. Among these people we have made ethnological collections that are complete with the exception of kayaks and two or three other articles. Kayaks were in existence, but not in common use, while of many of the smaller and commoner articles we secured numerous duplicates. Our archæological collections embrace the entire north coast of America, from Point Hope and the Diomede islands to Victoria island. Some of the points which I believe these archæological collections will go to establish are the following:—

(1). The Eskimo came to Alaska from the east and reached Bering strait in comparatively recent times, probably less than a thousand years ago. This opinion was, I believe, generally held before the time of our expedition, but we discovered many facts which materially strengthen that conclusion.

(2). Our excavations of house ruins and middens have shown that pottery was abundant in the earliest times of Eskimo occupation of the country as far east as Cape Parry. This is a contribution to knowledge of some importance, for it was previously commonly believed that the Eskimo had acquired the art of pottery making in recent times from the Indians in western Alaska. No museum had any pottery from farther east than Point Barrow and from that place only a few broken specimens had been obtained. It has, therefore, been considered that Point Barrow was the eastern limit of the potter's art, and some even believed that these specimens gathered at Point Barrow had been brought there as articles of commerce from Kotzebue sound.

(3). Our archæological work at various points on the coast from Cape Parry west and north to Point Barrow has shown that fish nets and tobacco pipes came in at approximately the same time from the west.

(4). The fashion of wearing labrets is shown to have preceded pipes and fish

nets by only a short period of time. The earlier type of labret was the oblong one worn in the centre of the lip, while the later type, subsequent to the introduction of tobacco pipes, is the modern round type worn under both corners of the mouth.

(5). The excavation of two village sites near Point Barrow indicated, among other things, that certain Eskimo traditions are, so far as they go, reliable. One of these villages was said to have been abandoned at the time that the other was first settled, and this was borne out by finding in the older site types of implements, which, while abundant there, were either rare or absent in the newer village. The abandonment of this site for the other one coincides approximately with the coming in of fish nets and pipes.

(6). The collection of stone lamps and stone cooking pots establishes the fact that those made of a certain type of potstone (steatite) came from quarries located about a hundred miles east of the Coppermine river. They must, therefore, have been carried as articles of commerce west along the coast even to Siberia, a fact which is also a matter of common knowledge among Eskimo still living. In other words, each tribe knows that its lamps and pots were secured from the next tribe east of them.

These are merely some of the broader generalizations which even a hasty examination of the collection will bring out. The less comprehensive, but equally significant facts concerning the collection can be brought out only by detailed comparative study of them.

The expedition, after reaching the Arctic by way of the Mackenzie river, spent the summer of 1908 in moving west along the coast, and during the following winter the main base of operations was on the Colville river. During that time sled journeys for the purpose of ethnological investigations were made as far west along the coast as Icy cape. Extensive collections of folk-lore were made and vocabularies recorded, chiefly at Point Barrow. The main part of the zoological work of this winter consisted of Dr. Anderson's expedition from the vicinity of Barter island south across the Endicott mountains for the purpose of securing mountain sheep and caribou, neither of which animals had ever been taken for scientific purposes in this district. He secured specimens of caribou and mountain sheep of both sexes and all ages, besides numerous examples of the smaller mammals and birds, while the collection the following spring included the eggs of most birds that nest in this portion of the Arctic. The summer of 1909 the expedition proceeded east along the coast, and the winter of 1909-10 was spent in the vicinity of Cape Parry, partly along the Horton river, and partly out on the tip of the cape itself. We found here, as well as in some other places, that the tree line differs from that of the charts issued by the Canadian Government. We also made numerous other corrections in the chart, perhaps the most important of which is the extension of Harroby bay, so that it lacks but a mile of cutting the peninsula of Cape Bathurst in two. We also showed that the River La Roncière is non-existent, that Horton river is a comparatively large stream, and that all the other rivers shown by Richardson as falling into Franklin bay are really nothing but small creeks, the longest of them being less than 10 miles in length. At several times during the winter of 1909-10 both Dr. Anderson and myself, as well as nine Eskimo of our party, had to go for some time without ordinary food and at one time we were compelled to eat up all the large mammalian skins which we had the previous year gathered together for scientific purposes. Dr. Anderson and one of the Eskimo also suffered a mild attack of pneumonia, which might have proved serious but for the fact that it occurred at a place where we had some provisions stored up. During this winter also most of our dogs died from a contagious dog sickness.

This winter had been spent about 100 miles east of the most easterly civilized community of the Eskimo. The country to the east of us was unknown

to us except for vague accounts which they had from their ancestors of the times, perhaps a hundred years or more back, when they used to associate with the tribes to the east. In the latter part of March, Dr. Anderson, who was then almost fully recovered from his severe illness, undertook the journey of 500 miles west to Fort Macpherson and Herschel island for the purpose of getting the mail which we hoped that whaling ships would bring in for us and to get certain stores, chiefly ammunition and writing materials, that had been sent to us through the whalers and through the Hudson's Bay Company. One of our Eskimo families was left behind near Cape Parry to take care of the scientific collection which had already been made and stored there.

I myself and three Eskimo started east along the coast on April 22, 1910, in search of the people which I thought might possibly exist somewhere along the Dolphin and Union Straits coast to the east. At first, for 100 miles or more, we found ruins of houses of wood and earth such as the western Eskimo build, but none of these were recent. The most easterly one that we happened to see was near the mouth of Crocker river, and it is probable that this was nearly the eastern limit of the wooden houses, for we found no traces of such structures anywhere near Coronation gulf. When we reached Point Wise, we found chips of wood cut from broken sticks with adzes, apparently not more than eight or ten years ago. As we proceeded eastward these became fresher and fresher until at Cape Bexley, on May 13, we found a deserted village of over fifty snow houses. This village, as we learned later, is the trading rendezvous for the various tribes of the neighbourhood in the autumn, and is usually abandoned about or before Christmas each year. Some trails lead east of this village, but most of them lead north across the sea out towards Victoria Land, which is in plain sight at this point, for the straits are only a little more than 20 miles wide. In the middle of the straits we found an encampment of thirty-seven Eskimo, none of whom had, either they or their ancestors, ever seen white men until they saw us—at least that is true so far as they know themselves and so far as I know from available literary sources. They had never seen Indians either, although they had dealt with other tribes of Eskimo who had seen Indians and although they had themselves occasionally seen traces of Indians on the mainland to the south. We found these people hospitable, well-bred, and altogether desirable men to live with, and began pleasantly on the first day an association of over a year which gave me unusual opportunities as an ethnologist of studying people uncontaminated by white influences. As a comprehensive report of our life among these Eskimo is to be issued in the future, I shall content myself here with the broadest generalities.

The inhabited country of which we were able to gather information comprises the southern end of Banks island, the southern half or two-thirds of Victoria island from Walker bay on the west coast to Albert Edward bay on the east coast, and the mainland from Kent peninsula to Cape Bexley. We did not ourselves visit the tribes that live in the western half of Victoria island nor those that live on the mainland east of Grey bay, but we talked with many individuals from these tribes who were visiting others. The fairly accurate knowledge of the people we dealt with extended as far east along the coast as King William's Land and as far west only as Baker lake. We found that their summer range is much farther south than had been previously known, for they wander over the entire country north of a straight line drawn from the south end of Bathurst inlet to the east end of Great Bear lake, as far west as the Dease river, which, however, they only occasionally cross. Though they migrate over belts of timber, they seldom stay in or near them, apparently, no doubt, through mistrust of the Indians, whose general whereabouts are known to the Eskimo, though no unfriendly contact had taken place. In our acquaintance with the Bear Lake Indians, I found that their fear of the Eskimo is far more intense than the Eskimo's fear of the Indians.

We saw rather less than a thousand individuals out of the total estimated population of a little over two thousand in the area described. They were in a prosperous condition as compared with the civilized Eskimo with whom we were familiar to the west. That is, they were better dressed, better fed, and had fewer wants that had to go unsupplied. The contrast in bodily health was striking. Whereas the civilized Eskimo to the west have, for the last half century, had a death rate so far exceeding the birth rate that the population of certain districts has been reduced to less than three per cent of that of 1848, it seems that these eastern Eskimo had a birth-rate equal to, and perhaps a little exceeding, the death rate. The typical village of two hundred inhabitants investigated had only two persons who were considered to be sick. One of them had suffered for two years of chronic dysentery, the other had been blind for seven or eight years. The contrast can be seen by comparing this village with a typical village of the civilized Eskimo, such as that at Baillie island. Here last year six died and three went insane, while about half of the remainder are seriously and obviously sick. In this same tribe I frequently purchased for scientific purposes every stitch of clothes a man had on at the time I saw him and in every case he had another complete set ready to put on and usually one quite as good as that which I had bought. Many had three or more complete changes of clothing, while in the civilized communities few men had even one decent suit of clothes.

The contrast in manners and customs was equally marked. The civilized Eskimo are inquisitive, always prying into your baggage or other property, generally prone to beg, and entirely without gratitude in the matter of presents. The uncivilized Eskimo made no impertinent inquiries, never tried to pry into our baggage, never begged, and always insisted on paying for whatever they got. As we proceeded east along Coronation gulf we came to tribes who had heard a good deal about white men from other tribes still farther east and some of them were inquisitive and inclined to beg. They told us that that was because they had heard from their neighbours to the east that white men liked to be so treated and expected to give things for nothing, which, they admitted, was not their custom.

Private ownership applies to all made articles and to raw materials that have been picked up or carried to a distance, but all sources of raw material and all food are in common. Skins of caribou and small seals (foetida) belong to the man who killed them, but the skins of large bearded seals (barbata) are shared among the men within sight at the killing. The flesh of the bearded seal is divided between the same families that get the portions of the skin. While they keep the skin, they give away a large part of the meat after it is cooked, so that the successful hunter's wife has the work as well as the honour of preparing the food and giving it away, while all share alike in the consumption of the food.

The clothing is preferably caribou skin at all seasons, but some of the tribes, notably those who hunt on the south of Dolphin and Union straits, are short of deer skins and have to use seal, marmot (spermophilus parryi), wolf, fox, and hare. Special rain-coats are made of seal skin for summer wear and boots coming to the knees are also sewn of this same material. The shoes worn at all seasons on snow, ice, or dry land are of seal skin. The skin of the bearded seal is used for stout thongs and that of the small seal for more slender ones. The best lines, such as fish lines and bow strings, are of braided sinew, preferably of the hind legs of caribou, while the back sinew of caribou is used for ordinary sewing.

The weapons of the people consist of the harpoon similar to the ordinary Eskimo type and made in some cases of native copper and sometimes of iron. The spears used from the kayak against caribou at the swimming places are usually headed with copper. The fish hooks are always of copper and the arrow points generally, although both stone and iron occur. The knives are double edged

with the handle of antler long enough for grasping with both hands, while the blade of copper or iron may be anything from 3 to 10 inches long. These are the hunting, housebuilding, or snow knives, while the ordinary form of crooked knife for whittling is not used. Most individuals had been able to secure iron for this very useful tool, although we found a few who were able to get nothing better for the blade than native copper. Much of the iron in use had come from McClure's ship, the *Investigator*, which the Eskimo discovered apparently a year or two after she had been abandoned in the Bay of Mercy on the north coast of Banks island. For something like thirty years the Eskimo of western Victoria Land used to make visits to the Bay of Mercy to secure iron, but at the time when men now barely full-grown were babies the supply of iron had given out, for the ship had been carried off to sea and broken up and nothing was left except the anchors and chains, which were unworkable with the primitive tools of the Eskimo. Pieces of the wreckage of the ship were found scattered, we were told, along the shores of Prince of Wales strait as far south as Pimento inlet, which throws an interesting side-light on the ocean currents in this quarter. The bows used in the hunting of all game except seals are of three pieces (Tartar type); the wood is spruce, but pieces of antler are used to strengthen the bow at the joints, and most of the springiness is furnished by a rope of twisted sinew on the back of the bow. The effective range of the weapon is about seventy-five yards, while the extreme range may be put at one hundred yards. At fifty or even at seventy-five yards the bow is an effective weapon. An arrow will in many cases fly a considerable distance on the other side after going through the chest of a wild caribou or even a polar or grizzly bear.

No permanent dwellings of any kind are erected by any of the Copper Eskimo —I call them so because every geographical descriptive term is either too large or too small and copper furnishes such a characteristic and important part of their material equipment. In winter they live in snow houses of the ordinary dome type, in villages of from three to thirty-three dwellings. Thirty-three is the largest number of houses I have ever found occupied by people who consider themselves members of one group, although at a trading rendezvous such as Cape Bexley larger numbers of houses are sometimes simultaneously occupied. A large house will accommodate two families of a total of nine or ten individuals, while five is perhaps the average number. In some cases adjoining houses have an interior connexion between them and in still others the outer door opens into a common hallway on either side of which is a door to the private houses. The exigencies of seal-hunting are such that a house is seldom occupied more than three weeks at a time, so that it is always vacated before it has a chance to become filthy. Apart from that, these Eskimo are really fairly good housekeepers. The net result, as to health, from living in these well ventilated and comparatively clean temporary dwellings (and tents in summer) is that the general health of the people is good, and pulmonary diseases in particular seem to be nearly or quite absent. This, of course, will all change very soon, when white men commence to live among them, for the tribes who at present are migratory will then become sedentary and will occupy the same dwellings the year round, as they do now whereever civilization has been planted.

In spring, perhaps about the 15th or 20th of May, usually, or a little earlier than that in Coronation gulf, but a little later in Prince Albert sound, the sun becomes so warm that the snow roofs of the houses cave in and they are then replaced by caribou skins, or seal skins if caribou skins are not at hand. Some time during the month of May the people move ashore from the snow villages which they have been occupying for nine months. When they reach the shore, or on the way at some small island, they will cache their stores of seal oil, their spare clothing, their heavy and valuable property, and, dressed only in nearly

worn out clothing and carrying practically nothing with them, they go north to Victoria island or the mainland in their search for caribou. A few tribes depend to some extent upon fish for their summer food. This is true notably of the Ekalluktogmiut of Albert Edward and the Akuliakattagmiut of Cape Bexley. The latter of these people spend their summer upon the lake south of Cape Bexley, from which they draw their name. This lake is the source of Rae river. Eggs also play a small part in the food supply of certain tribes and marmot in that of others, but in general all tribes depend in the main upon the caribou. A few of these are speared in swimming places by the mainland Eskimo that hunt south towards Bear lake, but most of them are killed by being driven into ambush or stalked in the ordinary way and shot with bow and arrow. Whenever more animals are killed than can be immediately consumed, the meat is cut up in thin slices and spread out to dry. When it is half dried, it is covered with heavy stones for safe keeping and abandoned by the people to be picked up again in the autumn. In general each tribe moves farther and farther inland as the summer advances and tries to leave behind it a trail of these caches of dried meat. Finally, when the snow overtakes them in the autumn, they return over the old route to the sea, picking up the caches as they go. Occasionally, where safe caches cannot be made,where an abundance of meat is gathered together, a single decrepit person is left behind to guard the meat depot until the return of the party.

The main importance of the summer hunt is not in storing of food for winter but rather in the securing of skins for winter clothing. For this at the present time the caribou are in sufficient numbers in the hunting districts of all the tribes, but the time is, of course, not far distant when this will all change. At present they live for nine months on seal, of which there is an inexhaustible supply in the ocean, and for three months on caribou, of which there is an abundant but soon to be exhausted supply, for when the traders bring in rifles, as they are beginning to do, the Eskimo will learn that caribou are easier to kill in winter than seal, and after a period of a few years, they will commence living for the twelve months through on caribou. Even if there were no wasteful killing, this would at least quadruple the destruction of the caribou. At present, too, each Eskimo has but one dog, because he finds it difficult to support more, and he needs but one dog for successful seal hunting. The dog with the Copper Eskimo at present is a hunting rather than a draught animal, although he is used for pulling sleds and for carrying pack loads on occasion; but when the rifle begins to make the killing of caribou easy, people will find that the support of dogs is also easy and large teams will be developed. It was so at Herschel island and at Baillie island, where men who forty years ago had a team of two dogs, ten years ago had typically at least two teams of six dogs each, which number has now again been cut down by the disappearance there of the caribou and the impossibility of supporting dogs on the scale of a few years ago. This increase of dogs, then, in the Copper Eskimo territory, will also increase the consumption of caribou meat, so that, if we make no allowance for it and for factors already considered and for a slight degree of wasteful killing or killing for pure sport, it is probable that the destruction of caribou will within the next ten years be increased tenfold over the present annual rate. This will mean a swift extermination of the caribou and the consequent impoverishment of the Eskimo, who are now well and warmly dressed but who will then be in a still worse condition than the Mackenzie Eskimo are now, for the natural trade resources of their country are less than those of the Mackenzie district and they will have less possibility of buying blankets and other substitutes for the reindeer skins.

The Copper Eskimo in their social organization may be described as anarchistic communists. There is absolutely no government in the sense of one man having authority over others by virtue of office or rank. Men have influence

in proportion to the general opinion of their intelligence and prowess. A man's influence, therefore, grows toward middle life and declines rapidly with age. Socially the sexes are equal. Women join in all discussions and are in every way treated with as much respect as men. In marriage relations they also are on the same level with their husbands, and theoretically a woman is always free to leave her husband when she wants to and he is, of course, equally free to leave his wife. Practically, however, we have seen cases where a woman who wanted to leave her husband was frightened by him into not doing so, for, along with the doctrine of equality is the doctrine of non-interference in the family affairs of others. Quarrels occur, and murders. These are followed by vendettas, which have no logical ending except in the splitting up of a tribe and the moving to a distance of all the members who composed one family or group of blood relatives. There is no punishment for crime except that a man who becomes intolerable is killed, but public opinion is very strong and the displeasure of the community acts in fact as a punishment. The force of public opinion is much stronger and much more keenly felt among the Eskimo than it is among us.

The language of the Copper Eskimo differs from that of the Mackenzie district somewhat more than the Mackenzie dialect differs from that of Point Barrow, but not so much as the Mackenzie dialect does from that of the inland Eskimo of Alaska. The difference is, in general, in the direction of the Greenland language. The difference between the Copper dialect and certain dialects of Greenland seems to be about the same as that between the Copper dialect and the Mackenzie dialect. The difference is naturally shown not so much by a different vocabulary as by grammatical or sound changes; for instance, the Mackenzie River 't' of verbs in the indicative mode appears as 'p' in Coronation gulf and Greenland. A curious thing is that although the Alaskan Eskimo and Greenland Eskimo can in general count up to twenty twenties or 400, the Copper Eskimo cannot count above six and, indeed, there are very few who can count that much. As a matter of practice, the word signifying 'many' is used for all numbers above three and in many cases for all numbers above two. In speaking of the killing of the caribou, for instance, a man will usually say that he killed many if he killed anything more than two, and the same applies to the announcement of the appearance of a band of caribou on the sky line; it will be one caribou, two caribou, or many caribou. The inflection of the language, however, will always give the number up to three, for all nouns appear in the singular, dual, and plural.

The religion of the Copper Eskimo is essentially the same as that of other groups east of Alaska. In other words, they seem essentially uninfluenced by Indian elements. There is no superior spirit nor are there in fact any spirits that are considered of higher rank or greater power than other classes of spirits. The several classes of spirits seem to differ chiefly in the physical form they take, in the clothes they wear, and in the places they inhabit. There are, for instance, spirits of the tide cracks and spirits of the air. There are also white men's spirits and Indian spirits, which do not seem to be identified with the souls of white men or Indians, but rather seem to be considered as spirits whose outward attributes are the same as those of white men or Indians. The tribes who had never seen white men nevertheless had all heard much about them from the east, and there were in each shamans who had white men for familiar spirits and who claimed to know the white man's language and to speak it in dealing with their familiar spirits. I heard a shamanistic performance of one of these and the language spoken was evidently a meaningless jargon and had no resemblance to any European language, for the characteristic sound was the 'tl' element of the Athabaskan Indians and the Mexicans.

There is great unclearness in all matters of religious thinking and none seemed to really know whether all these spirits were in the employ of shamans, although

some expressed their private and personal opinion to the effect that there were no spirits who had other masters in any human being. There are, however, some enchanted spirits which some do not explain at all and some explain by saying that they are the spirits of shamans who have died and left them without a master. Each shaman usually has more than one familiar spirit and many have five or six. These spirits differ in power, not according to what kind of spirit they are, but according to individual traits, exactly as men do. In other words, two shamans may each have for one of his familiar spirits a dweller in the tide cracks, one of which may be able to cure an illness that the other can do nothing with. Sickness is never thought of as being occasioned by natural causes but always as being the work of some shaman or evil-minded person who possesses a powerful spell or charm. When anyone is taken sick, the first thing, therefore, is to determine who made him sick and in what manner. A shaman is engaged and undertakes a séance. At first he dances and sings in his proper person but all of a sudden his attitude changes, his voice undergoes a transformation, and it is understood that he has been entered by one of his familiar spirits, who thereafter speaks through his mouth. Any reply to questions asked by the bystanders is possible in the form of a monologue, and the spirit explains why the person is sick and how he can be cured. Sometimes an evil spirit has been sent from a tribe in a different part of the country and has entered the patient. In that case, it must be driven out by powerful spells. In other cases, especially if one of the symptoms is a chill, it is believed that the soul of the sick man has been stolen and hidden somewhere. It is then the task of the shaman's familiar spirit to go all over the earth and look for the hidden soul and to bring it back. Success in this quest is shown by the recovery of the patient, while failure is indicated by a continuance of the illness or by death. Certain things and conditions, but notably the presence of blubber or other fat, make all spirits powerless, and if a stolen soul, for instance, has been hidden inside of a greasy bone, it cannot possibly be found, because a familiar spirit cannot look for it in any greasy place.

Many folk tales found among the Copper Eskimo are also found in Greenland and Alaska in their entirety. Others are represented both in Greenland and Alaska by certain combinations of elements which go to make them up, but which are combined in different ways in different districts. The game of cat's cradle and many other games are played by the Copper Eskimo in ways similar to those of the Alaskans. Cat's cradle games and the telling of certain stories are confined to the time that the sun is away in winter. The winter, except in times of scarcity, is the scene of dancing, story telling, and enjoyment, and it is very difficult to gather folk lore at any other time of year.

In physical characteristics the Copper Eskimo seem to differ from all other substantially pure blooded Eskimo known to me, in that tendencies to blondness are much stronger than elsewhere. In northern Alaska, for instance, where the Eskimo have been in contact with Europeans for over half a century and where whalers and other white men have freely taken Eskimo wives, there has not grown up any class of European-like beings, but among these more easterly isolated tribes, where European influences might be thought to be wanting, there are found many persons of strikingly European-like appearance. Out of something less than a thousand people seen by us perhaps ten or a dozen had blue eyes. Many of the men eradicate their beards, but of those who do not, a considerable number have fairly full beards of a colour lighter than the distinctly Eskimo black, ranging to a light brown tinged with red; while in western Victoria Land and in Dolphin and Union straits fully half the people have eye-brows lighter than the Mongolian black, ranging to light brown. No person seen has yellow hair of the Scandinavian type, but several have rusty red hair. This redness is more conspicuous on the forehead and becomes less towards the back of the head, just as the beards of the

more European-like individuals are usually dark in the middle of the chin and lighter towards the sides of the face.

The cephalic measurements of 206 individuals were taken. Of these, 104 were adult males. In considering the question of possible admixture of European blood, perhaps the most significant head measurements are those of the breadth of the face and the breadth of the head above the ears. The index obtained by dividing the figures expressing the breadth of the face by those for the breadth of the head shows more than 100 for Eskimo of unmixed blood.

In a summary published by the American Museum of Natural History, Professor Franz Boas gave the following indices for substantially pure blooded Eskimo:—

Herschel island	101
Greenland	105
Baffin bay	102
Alaska	104
East Greenland	102
Smith sound	102

In the same paper he gives the following for persons of mixed Eskimo and European descent:—

Labrador	96
West Greenland	95

My own measurements of 104 men of Victoria Land and the adjacent mainland gives a maximum of 97, which seems, so far as it goes, to differentiate these people in head form as much as they differ in complexion from such Eskimo as those of the Mackenzie river.

PART II.

ARCHÆOLOGY.

(*Harlan I. Smith.*)

The archæological work of the Geological Survey of Canada during 1912 has been a continuation of that of the previous year. Efforts have been made to diffuse archæological knowledge by means of tentative exhibits in the Victoria Memorial Museum. These exhibits have been selected from the national archæological collections. When the new exhibition cases are completed, the exhibits will be transferred to them and improved from time to time as our explorations result in specimens and data for filling existing gaps. One of these exhibits is the beginning of an assemblage intended to show each of the various types of prehistoric handiwork found throughout Canada, the variety and distribution of each. All the other exhibits are in a manner a cross reference to this, each intended to show the culture of a definite region. The regions at present illustrated are the Pacific coast of British Columbia, the Lower Columbia valley, the interior of British Columbia, the Prairie Provinces, Ontario, Quebec, the Maritime Provinces, and the Arctic. Of these, those of British Columbia and Ontario are fairly representative. Here not only educators and students, but all Canadians may make use of the collections, and such use will soon dispel the unfortunate idea that a modern museum is merely a storehouse for curiosities or abnormal objects. Some member of the staff is always ready to meet classes or visitors and to give such help as is possible, while informal talks in the museum may be arranged, especially if request is made a few days in advance. Serious students may have access to the study material in addition to the selections on exhibition.

A popular guide to the collection from the interior of British Columbia has been sent to the editor. When published, this will serve as a pattern for the completion of the similar guide to the collection from the Pacific coast and the one to that from Ontario. When such guides have been completed for all the areas, they should serve, taken together, as a popular manual for the archæology of Canada. Lantern slides have been ordered showing a comprehensive series of the photographs taken of the season's intensive explorations in the Roebuck site in Ontario, and of all the pictures selected for illustration in the popular guides. The stock of slides is thus becoming more and more useful for illustrating the archæology of Canada in any city of the Dominion. As time goes on, lectures illustrated with selected series of these slides may be prepared and loaned for educational purposes. The labels prepared last year have been received and used in the exhibits.

The efforts begun last year to increase the archæological knowledge of Canada by means of original research and systematization have been continued. The field work has been carried on according to a plan for a systematic study of the archæology of the whole of Canada, and the results have met all expectations.

I conducted a reconnaissance near Ottawa in a part of the St. Lawrence lowlands of the eastern woodland area. This particular locality includes part of both the Algonquian and Iroquoian linguistic areas. More particularly this work was along the northern side of the Ottawa river, in the Gatineau valley, in the Nation valley, and on Rideau lake. Mr. W. J. Wintemberg carried on a reconnaissance in the Ottawa valley above the city of Ottawa and nearly the whole length of the

Nation valley. The work of reconnaissance resulted in the locating of a number of cave-dwellings in the Laurentian mountains near the north side of the Ottawa river. Pottery of an Iroquoian type has been found in these caves, which are believed to be worthy of thorough exploration. Specimens were found or seen in the hands of the people of the country every two or three days and village sites were found nearly as frequently. These sites are probably of Algonquian origin. They are all rather small in extent and the deposit is shallow. In general, they are near the streams on suitable camping places for canoe parties. One on Rideau lake at Stone House point or Plum point is the largest.

Intensive exploration under my general direction and the immediate charge of Mr. Wintemberg was carried on in a village site near Roebuck, one of four large Iroquoian village sites situated near Spencerville and the head-waters of the Nation, within 8 miles of Prescott on the St. Lawrence river. In all there are five sites within a radius of about 4 miles, four of them being extensive. Many of the people in this vicinity have small archæological collections. This type of site is usually on the top of a low hill near a spring or small stream, a location entirely different from that of the sites along the Ottawa river and in the lower Nation valley. The sites are indicated by black or dirty spots made up of the rubbish of habitation. Any one of these large sites would furnish material for explorations extending over many months, if not several years, but the results obtained in a shorter time would probably be sufficient to characterize the culture.

The work in the Roebuck site has been the largest intensive and the most thorough systematic archæological exploration carried on in the Province, or, for that matter, in Canada east of the Rocky mountains. Charred corn and beans were found which, together with the fact that this site, like the other four, is not on a very large stream, suggests that the people were agricultural. Arrow points chipped from stone were exceedingly rare and those made of antler were also uncommon. The grooved axe has not been found and even the celt is represented by only a few specimens, but fragments of pottery are very plentiful, as are also sharpened bones, perhaps used as awls. Fifty-one human skeletons have been found, but the burials with one exception were unaccompanied by artifacts. The skeletons show that the people suffered from bone diseases and that there was a considerable infant mortality. They were apparently all of one physical type. Part of the material was put on temporary exhibition, and all of it is to be unpacked, cleaned, catalogued, and studied, so that an illustrated report may be written upon the site and its culture. A popular guide, abstracting the scientific report, may then be written to accompany the exhibition.

Mr. Wintemberg, during nine days in November, at the Provincial Museum, Toronto, secured for the files copies in duplicate of all the archæological locations in Ontario and Quebec recorded by the late Dr. David Boyle on his Archæological Map of Ontario, and so far as known of all Canadian archæological locations in the archives of that museum.

Dr. T. W. Beaman, of Perth, a volunteer worker, undertook general charge of the preliminary exploration of the supposed Algonquian site at Stone House point on Rideau lake. Mr. C. C. Inderwick, also a volunteer worker who spent some time assisting Mr. Wintemberg in order to familiarize himself with methods of excavation, assumed immediate charge of the preliminary exploration at Stone House point.

Mr. G. E. Laidlaw continued his studies of the archæology of Victoria county, Ontario, and presented maps and an extensive manuscript, summarizing our present knowledge of the archæology of that region.

Mr. W. B. Nickerson undertook the initiation of the Government archæological work in the Great Plains along the special lines laid out. The work was confined to reconnaissance in Manitoba near Winnipeg, preparatory to intensive

work. Some specimens, as well as information maps, and photographs were secured. Over seventy items were sent in for the files as his report.

The chief addition to the archæological collections resulted from the intensive exploration in the Roebuck site, from which one hundred and thirty-five boxes were sent in by freight. This collection, together with the specimens resulting from the reconnaissances in Quebec, Ontario, and Manitoba, well illustrates the general advisability of securing archæological collections as a by-product of archæological research rather than by purchase. The results are not selected or culled, but represent as nearly a normal culture as it is possible to obtain. The extra expense of making the collection does not greatly augment the cost of the research. Including the results of the research work, the notes, plans, and photographs, all of which furnish material for publications, scientific and otherwise, and the duplicate specimens which may be sent to other museums throughout the country, the total expense is less than an equally valuable collection when made by any other method. The collections should be as much a result of efforts to increase knowledge as the exhibits are intended to diffuse that same knowledge.

Other accessions, received since December 7, 1911—the date of the last accession listed in the previous report—include those sent in by officers of other divisions of the Geological Survey as follows:—

A grooved hammer made of stone, collected in Alberta by Mr. Levi Sternberg;

Points chipped from stone, and a tomahawk made of iron, collected in Ontario by Mr. M. Y. Williams;

An adze head made of stone, collected near Salmon river in Yukon by Dr. D. D. Cairnes;

Artifacts chipped from stone, collected in the southern interior of British Columbia by Mr. C. W. Drysdale;

Two artifacts from the Gatineau valley, Quebec, collected by Dr. Edward Sapir;

Artifacts from Ontario, collected by Mr. F. H. S. Knowles;

Artifacts from Essex county, Ontario, collected by Mr. C. M. Barbeau; one point chipped from stone from New York, collected by Mr. F. W. Waugh.

Gifts were received as follows: artifacts from near the mouth of Louis creek, in the North Thompson valley, about 35 miles above Kamloops, British Columbia, sent forward by resident engineer Mr. J. C. Embree; artifacts from section 2, division 4, Canadian Northern Pacific railway, sent forward by resident engineer, Mr. R. W. Moore, both gifts made by order of Mackenzie, Mann & Company; two hoes made of bone, collected by Mr. Robert F. Gilder, near Omaha, Nebraska, gift of Mr. Harlan I. Smith; a copper bead, and two casts of artifacts from Ontario, gift of Mr. W. J. Wintemberg; bead made of shell, from Lytton, British Columbia, gift of Rev. H. J. Underhill; three pieces of rhyolite, a gouge made of stone and a celt made of stone, from Maine, and material from a shell heap in Massachusetts, gift of Prof. Frank G. Speck; chipped chert, from Ontario, gift of Mr. John McGaw; pipe made of pottery, from Ontario, gift of Mr. Andrew K. Leeson; an arrow point from Edwardsburg township, Grenville county, Ontario, gift of Mr. Ernest Kingston, Spencerville, Ontario; spear point rubbed out of slate from Edwardsburg township, Grenville county, gift of Mr. Andrew Miller, Spencerville; pipe made of pottery, from Augusta township, Grenville county, gift of Mr. William McKinley, Roebuck; one object from Edwardsburg township, Grenville county, gift of Mr. Alfred Stirton, Spencerville; bead made of soapstone from Roebuck site, Grenville county, gift of Mr. Frederick Smith, Prescott; two beads made of soapstone from Roebuck site, and stone celt from Edwardsburg township, Grenville county, gift of Mr. Frederick Anderson, Roebuck; two fragments of pottery from Manitoba, gift of Mr. E. W. Darbey; two grooved hammers made of stone from near Snowflake, Manitoba, gift of Mr. Robert Neil; pendant made of shell, from near Snowflake, Manitoba, gift of Mr. Eli Sims; eight fragments of

pottery from Manitoba, gift of Dr. J. B. Tyrrell; a fragment of pottery from that part of the Roebuck site on the farm of Mr. Nathaniel White near Roebuck, Ontario, gift of Mr. White; beads and fragments of pottery from Sourisford, Manitoba, gift of Mr. David Elliot.

It is not generally the policy of the archæological section to purchase specimens.

ON ARCHÆOLOGICAL WORK IN ONTARIO AND QUEBEC.

(*W. J. Wintemberg.*)

Beginning May 8, I assisted in a reconnaissance in Quebec on the north side of the Ottawa river above Hull from Eardley to Quyon. Near Chats falls, a small site, apparently of Algonquian origin, was discovered and a number of specimens were found. From Quyon I proceeded alone, stopping at Campbell Bay, Bryson, Fort Coulonge, and Waltham. Inquiries for both information and specimens were made of practically everyone met outside the towns and of the prominent people in them. Some artifacts were obtained by gift at Fort Coulonge and several copper objects were procured on the east range of Allumette island. Information was secured regarding the location of a site on the south shore of the island.

Returning on the Ontario side of the Ottawa river, at Pembroke, inquiry resulted in the location of other sites where specimens have been found. On May 20 we began below Ottawa at Casselman, in the valley of the Nation river. Personal search here resulted in the location of three small sites and the collection of a few specimens. Proceeding alone I traversed the Nation valley nearly to its source, stopping and making inquiries at South Indian, Chrysler, Chesterville, Winchester Springs, Winchester, and Kemptville. Information as to the location of sites and as to finds of specimens was frequently obtained. Two small sites, one probably Algonquian and the other apparently Iroquoian, were discovered on the bank of the Nation river near Chesterville. At the latter site, chipped points made of slate for arrows and spears, celts, pottery, and other specimens were secured. Near Kemptville two Algonquian sites were found and on one of these a large number of fragments of pottery and a few points chipped from stone. Notes in duplicate for the two permanent files were made of all the information secured.

In Spencerville is a small site, and immediately north of the town is a large one; another lies northeast, one is west, and, in the country nearer the St. Lawrence, there is another, making a total of four extensive sites and one small one, all within from 2½ to 4 miles of Spencerville. All these sites were visited. The material found on them appears to be of Iroquoian origin. The Roebuck site, one of these, is immediately east of the village of Roebuck, on lots 2 and 3, concessions VI and VII, Augusta township, Grenville county. The site is large, covering about eight acres of land on the farms of Mr. James Kelso, Mr. Nathaniel White, Mr. Alden Starr, and probably extending on to that of Mr. George Dunbar. Intensive explorations were begun June 17 and carried on until October 28. The excavation was confined to that part of the site lying on the farms of Mr. Kelso and Mr. White, to both of whom we are indebted for permission to work on their land and for many other courtesies. The site is situated on a sandy point, perhaps 20 feet high, between two creeks—one the south Indian creek (an affluent of the Nation river, until recently navigable for canoes), with its swampy margins, and on the northeast a small, swampy branch of this creek. Guest, who visited this place in 1854,[1] describes this point as an artificial mound. On the natural yellowish sand of this site there are about twenty dark spots composed of refuse of habitation, each deepest in the middle. On top of the hill the maximum depth of the spots is about 18 inches, but on the south side of the point, in the spots extending to the bottom, where the slope to the swamp is steepest, the refuse in places reaches a depth of 4 feet.

[1] Cf. Smithsonian Report, 1856, p. 271.

Three assistants were employed during June, four in July, one in August, three in September, and four in October. One hundred and thirty-five boxes of material were shipped to the museum in addition to some small packages sent by mail.

The palisade originally surrounding the village was readily traced for about three-fourths of the way by excavating and finding round blacks pots (the moulds of the post holes) occurring at nearly regular intervals in the yellow sand. Extended excavation would undoubtedly result in completing the tracing. On the south side, where the slope is steepest, there was only a single row of posts, but in several places on the east and north beside the single row there were two and three rows.

Excavations were made in one of the three springs at the site at Mr. Smith's special request. The spring selected was the one into which material might work its way. Hitherto no attempt had been made in Canada to examine springs, and while only a few specimens were found, the securing of articles made of wood, which in any other place except under water would probably long since have decayed, adds to our knowledge of this branch of primitive technology.

No objects made of copper or other metal were discovered. Some unusual forms of bone objects were collected. There are also many specimens made of antler, one carved in the shape of a phallus. Objects made of shell were very rare. A few unios were found with a perforation through the side. Others were rubbed down on the sides, while still others showed evidence of having been used as scrapers. One of the specimens was evidently a paint dish, as some red paint still adheres to it. Three objects made of marine shell (a large conch), and a fragment of a quahog shell were found.

The large number of animal bones found shows that the people subsisted in part on animal food. Although about thirty points for arrows made from antler were found, there were only a few chipped from stone. This suggests that other objects, possibly sharp bones, of which many were found, were used. Traps, too, may have been largely employed. It also seems to indicate an absence of frequent wars near the village. Cores, chips, and pieces of chert, jasper, or kindred stone suitable for chipping, were represented by only two or three specimens. Several harpoon heads—some bilateral, others unilateral—and specimens of fish hooks made of bone in all stages of manufacture, from the rough bone to the finished hook, were found. The presence of charred corn, corn cobs, sunflower seeds, squash seeds, and beans shows that the inhabitants of this site were an agricultural people.

Rubbing stones and small mortars were common. Fragments of pottery bearing a great variety of patterns were very numerous. They are of Iroquoian type. Some have handles. A few very small vessels were found entire. Celts made of stone were occasionally found, while hammer stones were numerous. Awls made of bone outnumbered all other specimens made of this material. Hundreds of them were found. Two specimens of textile work were secured, a carbonized piece of rope, apparently made of corn husks, and what appears to be a piece of coarse matting.

Pipes made of pottery were plentiful, all of which were broken. Some are very unusual forms, including 'portrait' types. Broken stems of two pipes made of stone were also found. There were a large number of discs chipped from fragments of pottery, some of them with the edges rubbed smooth, that were possibly used in games, and some perforated discs made of soapstone.

Fifty-one human skeletons, usually in the yellow sand below the refuse, were found. The depth of burial varied. Some were within an enclosure, as was indicated by moulds of post holes surrounding them in the yellow sand. There were three double burials. The remains were buried in various directions as to orientation, although about fifty per cent of them were lying with their heads to the east or west. They were usually on the side with the legs always flexed and the arms

nearly always so. Part of these were skeletons of children. Most of the bones were in a good state of preservation. One small pottery vessel of graceful form was found with one of the skeletons. The others were unaccompanied by artifacts. Numerous stray human bones were found in the refuse, and some of these had been partly burned. All the bones were collected for the museum.

As nothing of European manufacture or even showing European influence was encountered, we must conclude that the site was abandoned before, or shortly after, the advent of Europeans into the St. Lawrence valley.

ON AN ARCHÆOLOGICAL RECONNAISSANCE OF MANITOBA.

(*W. B. Nickerson.*)

The five weeks at my disposal in 1912 limited the contemplated archæological reconnaissance of the prairie provinces of Canada to Manitoba, and the work done is only a beginning in that Province. In Winnipeg, such historical data and information as are obtainable only through personal interviews were collected. Visits were made to the mound sites on Red river at St. Andrews rapids. Southern Manitoba west of the Red River valley, adjacent to the Deloraine and Estevan lines of the Canadian Pacific, was covered. At all points visited an intelligent interest in our plans and purposes was found and encouraged. Correspondence relative to archæological fields, and material objects for the national collections, were solicited, and in some instances secured. An endeavour was made to establish a permanent co-operation through correspondence.

The earthworks in the Souris valley, in township 2 north, 27 west, in the southwest corner of the Province, comprise thirty or more mounds, five or more village sites, and a rectangular walled enclosure. Of the mounds, eight are low and long, locally termed 'grades'; the remainder are circular mounds 2 to 5 feet high. Mr. David Elliot, living in the vicinity, has collected from his fields and from the mounds much interesting material, and presented a representative series of grooved stone mauls and hammers, some potsherds, a few beads, and other objects. Errors in topography as sketched in Jephson's survey of 1880, in section 33, were found, and corrected on the manuscript archæological sketch map of the series. An accurate and comprehensive survey should be made next season.

The knolls about Killarney were examined and a sketch map was made of the district adjacent to the southeast end of Lake Killarney, where a campsite and what is possibly a mound were found. Pilot mound, in township 3 north, 11 west, a lone hill of cretaceous shale, was examined. A burial mound now opened crowned the summit of this hill. In the west across the deep valley of the Pembina, lies the mound plain above Rock lake. On this plain above the east end of the lake, in township 3 north, 13 west, are eight mounds, four in one group, the others scattered at wide intervals over the plain. In the southeast is Star Mound hill, west of the village of Snowflake, in township 1 north, 10 west. It is, like Pilot mound, an isolated hill, said to have been named Dry Dans hill in early times. It covers a larger area than Pilot mound, and a spring issues from its southern side about halfway down the slope. The summit of the hill is crowned by a circular mound 5 feet high, having on the north a gradually tapering extension. East and southeast of this hill, in township 1 north, 9 west, on the plain above the Pembina valley, are eight or more mounds. There is one east near Mowbray, in township 1 north, 8 west. Two more mounds are found in this township, on the plain north of the river, and mounds are said to be found on both sides of this valley beyond the line of North Dakota.

'Calf mountain', 1½ miles southwest of Darlingford, was visited. It is circular, 15 feet high, among similar morainic knolls, and is probably natural. Just east of Manitou, on the summit of the highest elevation between Manitou and Darlingford, is a mound 2 feet high. On the summit of the Pembina mountain, just southwest of Morden, is one 3 feet high. The trail known in early historic times as the Missouri trail, from Winnipeg, passed near the Morden mound, thence via 'Calf mountain,' and crossing the Pembina river near the Snowflake mounds, passed westward south of Star Mound hill.

Permission was secured for opening mounds at Sourisford, Rock Lake, Snowflake, and Morden, and the work should be commenced without unnecessary delay.

PART III.

PHYSICAL ANTHROPOLOGY.

(*E. Sapir.*)

An important aspect of the anthropological research of the division was inaugurated this year by the study of the physical anthropology of the Iroquois Indians. Mr. F. H. S. Knowles, of Oxford University, undertook charge of this work, spending a period of about four months in field research at Six Nations reserve, Ontario, and upwards of a month in museum work connected with physical anthropology in Ottawa. Mr. Knowles' work centred chiefly on procuring a series of detailed head and body measurements of Iroquois men, women, and children living on the reserve. Two hundred and eighty-eight anthropometric schedules of as many individuals were obtained, forming the basis of a study of the physical characteristics of the Iroquois Indians. It is intended to add considerably to this material in future research, so that the anthropometric study of the Iroquois may be made thoroughly adequate. In connexion with his field research Mr. Knowles also secured forty-five specimens of hair from as many Iroquois individuals. It is to be deeply regretted that Mr. Knowles' illness during much of the time that he spent in the field somewhat reduced his actual field period of research, and that continued illness has made it impossible for him to finish the more detailed summary report of his work which he had begun. It is hoped that this report may be included in the summary report of the division for 1913.

Incidentally to his work among the living Indians, Mr. Knowles dug up an ossuary close to the reservation. Besides a certain amount of archæological material, Mr. Knowles procured a considerable body of interesting skeletal material consisting of twenty-nine skulls, twenty-eight long bones, and thirty-one miscellaneous bones, including a large number of teeth. This skeletal material, together with the fifty-one skeletons which Mr. W. J. Wintemberg has obtained from the Roebuck site near Spencerville (see his report in Part II), forms a valuable foundation for the study of the physical anthropology of the Iroquoian tribes of Canada, as there seems little doubt that the remains found both at the Roebuck site and the ossuary near Tuscarora, Ontario, belong to Iroquoian peoples. The eventual comparison of the results obtained from a study of such remains with those obtained from anthropometric research among the present day Iroquois, who have been subjected to very considerable white influence, will no doubt prove suggestive.

Accessions in Physical Anthropology.—The accessions for the year in physical anthropology have been due to either gifts and material secured by Survey field men not connected with the division, or as the result of archæological field work undertaken by the division. The gifts embrace:—

- From B. O. Strong, constable of the R.N.W.M.P., bones of a child, from near Windthorst, Sask.
- From Andrew Berg, of Kanai, Alaska, human cranium.
- From A. W. Phillips, Resident Engineer, skull, from near Kamloops lake, B. C.
- From J. C. Embree, resident engineer, human bones, from near mouth of Louis creek, North Thompson valley, about 35 miles above Kamloops, B. C.

From W. H. Melanson, resident engineer, human skeleton, from near Kamloops lake, B. C., and skull and bones from Canadian Northern Pacific railway, Station 1046.

From R. W. Moore, resident engineer, human bones, from section 2, division 4, C. N. P. R.

From E. Webb, resident engineer, skull, lower jaw, and other human bones, from near Ashcroft, B.C.

The last five accessions are due to the kindness of Mackenzie, Mann & Company, who have given orders to their engineers at work on the construction of the Canadian Northern railway to forward all skeletal material that they come across in the progress of their work to the Victoria Memorial Museum.

There have been obtained by a Survey man not connected with the Division of Anthropology the following:—

By C. M. Sternberg, 3 fragments of human skull from region of Red Deer river.

Material in physical anthropology obtained by field men working for the Division of Anthropology consists of:—

By J. A. Teit, Spence Bridge, B.C., part of eight human skeletons and one skull, from near Spence Bridge, B.C.

From W. J. Wintemberg, fifty-one skeletons, from Roebuck site (see Wintemberg's report in Part II).

From F. H. S. Knowles, skeletal material from near Tuscarora, Ont., as above.

From F. H. S. Knowles, forty-five specimens of hair of living Iroquois, from Six Nations Reserve, Ont.

DRAUGHTING DIVISION.

(C.-Omer Senécal.)

Considering the unusually large demand made this year on this division, and notwithstanding that the work was seriously hampered owing to sickness among the staff during the typhoid outbreak, and to the resignation of one skilled draughtsman, very satisfactory progress was made. At present the division comprises a chief officer, twelve draughtsmen, and one clerk.

From the beginning of June, in order that the mapping work for the Twelfth International Geological Congress might be completed in time for the opening of this convention, a special staff was detached for the compilation and drawing of the large number of maps required to accompany the Congress excursion guide-books, while the remainder of the staff attended to the routine work of the division and partly to other mapping work for the Congress. These maps, which are being prepared in sets of five to twelve subjects per sheet, are in very fair progress and all the nineteen sets are expected to be issued early in 1913.

Attention was, as usual, given by the chief of the division to the work of the Map Committee and to that of the Geographic Board of Canada of which he is also a member.

During the year, in addition to the large number of drawings, sketch maps, diagrams, sections, etc., which were made by the staff of this division, to illustrate geological memoirs, a large amount of artistic or free-hand drawing for the Anthropological Division, also devolved upon the draughtsmen. This kind of work will henceforth necessitate the exclusive attention of one of the draughtsmen, who is specially trained in that line.

There was also a considerable increase in the correspondence of the division; letters, memoranda, map specifications, reports, etc., sent out, amounted to 608, while 636 were received.

In the near future, a systematic card catalogue of the map records will be undertaken, the accumulated material requiring immediate attention. As the work passing through this division is increasing rapidly from year to year, it is deemed advisable that more assistance be afforded by the appointment of another skilled draughtsman and a custodian of records in the map-room.

The maps listed below, were, at the end of the year, in the printer's hands.

Maps in Hands of King's Printer, December 31, 1912.

Series A	Publication number	Title	Sent to King's Printer
26	1162	Bathurst, N.B. Topography	1 June, 1911.
27	1163	" Geology	1 June, 1911.
33	1179	Nanaimo Sheet, B.C. Topography	11 July, 1912.
39	1185	Province of Nova Scotia	31 Aug., 1911.
40	1210	Bighorn Coal Basin, Alta	17 Oct., 1911.
41	1191	Duncan Sheet, B.C. Topography	8 July, 1912.
43	1193	Sooke Sheet, B.C. Topography	8 July, 1912.
45	1195	Tulameen, B.C. Topography	29 Aug., 1911.
46	1196	" Geology	29 Aug., 1911.
49	1199	Orillia Sheet, Ont. Topography	17 Oct., 1911.
50	1200	Portland Canal Mining Area, B.C.	17 Oct., 1912.
52	1202	Serpentine Belt, Eastern Tps., Quebec	6 Oct., 1911.
53	1208	Southeastern Nova Scotia	26 Sept., 1911.
55	1221	Alberta, Saskatchewan, and Manitoba	22 May, 1912.
62	1237	Nelson and Vicinity, B.C.	10 July, 1912.
64	1244a	Gowganda (North sheet), Ont	9 July, 1912.
64	1244b	" (South sheet), Ont	9 July, 1912.
74 to 90	1260 to 1276	Geology of the 49th Parallel, 17 sheets	12 Jan. to 12 May, 1912.
—	664	Lake Winnipeg, Man. Reprint	24 June, 1912.
—	750	Grenville Sheet, Ont. and Que. Reprint	26 Aug., 1912.
—	929	Cascade Coal Basin, Alta. Sheet 1, Reprint	19 July, 1912.
—	931	" " Sheet 2, "	"
—	933	" " Sheet 3, "	"
—	935	" " Sheet 4, "	"
—	—	Geological Congress maps, Set No. 1 (5 maps)	27 Sept., 1912.
—	—	" Set No. 2 (6 ")	3 Oct., 1912.
—	—	" Set No. 3 (6 ")	3 Oct., 1912.
—	—	" Set No. 4 (7 ")	15 Oct., 1912.
—	—	" Set No. 5 (11 ")	12 Nov., 1912.
—	—	" Set No. 6 (10 ")	6 Dec., 1912.
—	—	" Set No. 7 (4 ")	15 Nov., 1912.
—	—	" Set No. 8 (12 ")	19 Nov., 1912.
—	—	" Set No. 9 (7 ")	30 Dec., 1912.
—	—	" Set No. 10 (9 ")	30 Dec., 1912.

The following maps are being engraved by the office copper engraver:—

Tobique, N. B. (Engraving completed).
Victoria Sheet, B. C.—Areal Geology.
Victoria Sheet, B. C.—Superficial Geology.
Saanich Sheet, B. C.—Areal Geology.
aanich Sheet, B. C.—Superficial Geology.

Besides the above, about 100 zinc cut drawings of sketch maps, diagrams, figures, indexes, etc., to illustrate reports in course of publication, have been delivered to the Director.

During the same period, the following map editions were received and issued to the public:—

List of Map Editions Published During the Year 1912.

Series A	Publication number	Title	Remarks
17	1201	British Columbia.—Southern Vancouver island. Scale 6 miles to 1 inch......	Geological reconnaissance.
19	1147	" Lardeau, West Kootenay district. Scale, 4 miles to 1 inch..	Topography.
29	1167	" Mother Lode and Sunset mines, Deadwood. Scale, 400 feet to 1 inch..........	Topography.
36	1182	" Beaverdell, Yale district. Scale, $\frac{1}{62500}$..........	Topography.
47	1197	" Law's Mining Camp, near Tulameen. Scale, 600 feet to 1 inch	Economic geology.
54	1219	" Nanaimo Coal Area, Vancouver island. Scale, 1½ miles to 1 inch..........	Economic geology.
56	1222	" Skagit valley, Yale district. Scale, $\frac{1}{62500}$..........	Areal geology.
69	1247	" Route map of part of Naas river. Scale 8 miles to 1 inch..	Exploratory.
—	—	" Portland Canal Mining district and portion of Salmon and Nass valleys. Scale, 2 miles to 1 inch..........	Geological diagram.
—	—	" Workings on Alpha and adjacent mining claims, Observatory inlet. Scale, 400 feet to 1 inch..........	Geological diagram.
—	—	" Portion of Observatory inlet. Scale, about 4 miles to 1 inch	Geological diagram.
—	1229a	Yukon.—Wheaton map-area. Scale, 2 miles to 1 inch..........	Geological diagram.
51	1201	Alberta, Saskatchewan, and Manitoba.—Scale 35 miles to 1 inch..........	Economic geology.
—	339	Manitoba.—Northwestern portion of. Scale, 8 miles to 1 inch. (Reprint, 1912)	Geology.
—	—	" Northern end of Lake Agassiz. Scale, 35 miles to 1 inch..........	Diagram.
31	1177	Ontario.—Larder lake, Nipissing district. Scale, 1 mile to 1 inch..........	Economic geology.
—	—	" West Shiningtree Area, Sudbury district. Scale, 1 mile to 1 inch...	Geological diagram.
—	964	" Algoma and Thunder Bay. Scale, 8 miles to 1 inch. (Reprint, 1912)	Exploratory.
32	1178	Ontario and Quebec.—Larder lake and Opasatika lake. Scale, 2 miles to 1 inch	Economic geology.
38	1184	Quebec.—Danville Mining Area, Arthabaska, Richmond, and Wolf counties. Scale, 1 mile to 1 inch..........	Economic geology.
35	1181	New Brunswick.—Parts of Albert and Westmorland counties. Scale, $\frac{1}{62500}$....	Economic geology.
—	—	Nova Scotia.—Plan of Brookfield Gold district, Queens county. Scale, 250 feet to 1 inch (new edition)..........	Economic geology.
—	—	" Plan and Section of Oldham Gold district, Halifax county. Scale, 500 feet to 1 inch (new edition)..........	Economic geology.
—	—	" Section of Libbey Fissure vein, Brookfield Gold district, Queens county. 250 feet to 1 inch (new edition)..........	Economic geology.

LIBRARY.

(M. *Calhoun, Acting Librarian.*)

During the calendar year, 959 volumes and pamphlets were received as gifts or exchanges, including—besides periodicals—maps, reports, and publications of foreign Geological Surveys, together with Memoirs, Transactions, and Proceedings of the scientific societies of Canada and other countries.

503 volumes were added by purchase, costing $1251.09.

114 periodicals were subscribed for.

203 volumes were bound during the year.

The rearrangement of the books, according to the Cutter system of classification adopted last year, has been completed, thus greatly increasing the facilities for practical reference. A modern dictionary catalogue of all the volumes in the library is being compiled.

Reading tables and periodical racks have been installed, which add to the convenience and comfort of those using the library.

PUBLICATIONS.

The Following Reports Have Been Published Since January 1, 1912.

No.

940. Reprint: Report on Graham island, B.C. By R. W. Ells. Published April 24, 1912.
1121. Memoir No. 13: Southern Vancouver island, B.C. By Charles H. Clapp. Published September 6, 1912.
1175. Memoir No. 21: Geology and Ore Deposits of Phoenix, Boundary district, B.C. By O. E. LeRoy. Published September 16, 1912.
1204. Memoir No. 24: Preliminary Report on the Clay and Shale Deposits of the Western Provinces. By Heinrich Ries and Joseph Keele. Published July 26, 1912.
1211. Memoir No. 27: Report of the Commission appointed to investigate Turtle mountain, Frank, Alta. Published March 1, 1912.
1213. Memoir No. 28: The Geology of Steeprock lake, Ont. By Andrew C. Lawson. Notes on Fossils from Limestone of Steeprock lake, Ont. By Charles D. Walcott. Published April 19, 1912.
Reprint from Memoir No. 28: Notes on Fossils from Limestone of Steeprock lake, Ont. By Charles D. Walcott. Published May 11, 1912.
1218. Summary Report of the Geological Survey for the calendar year ending December 31, 1911. Published October 16, 1912.
1218a. Reprint from Summary Report, 1911: Reconnaissance of the Shuswap lakes and vicinity (South-central British Columbia). By R. A. Daly. Published September 12, 1912.
1218b. Reprint from Summary Report 1911: Anthropological Division—Ethnology, E. Sapir and others; Archæology, Harlan I. Smith. Published October 29, 1912.
1234. Instructions regarding the Collection of Zoological Specimens for the Victoria Memorial Museum; Zoology. By P. A. Taverner. Published Aug. 27, 1912.

French Translations.

(*M. Sauvalle.*)

1060. Report on a portion of Northwestern Ontario traversed by the National Transcontinental railway, between Lake Nipigon and Clay lake near Kenora. (No. 1059). By W. H. Collins. Published April 25, 1912.
1087. Report on Geology of St. Bruno mountain, Que. (No. 1077). By J. A. Dresser. Published July 12, 1912.
1157. Report on the Geology and Petrography of Shefford mountain, Quebec. (No. 776). By J. A. Dresser. Published November 6, 1912.
1158. Report on Geology and Petrography of Yamaska mountain (No. 888). By G. A. Young. Published November 6, 1912.
1159. Report on Geology and Petrography of Brome mountain (No. 902). By J. A. Dresser. Published July 6, 1912.
1187. Report on the Haliburton and Bancroft Areas, Ont. (No. 1186). By Adams and Barlow. Published July 6, 1912.
1120a. Summary Report of the Geological Survey Branch of the Department of Mines for 1909.
1170a. Summary Report of the Geological Survey Branch of the Department of Mines for 1910.

ACCOUNTANT'S STATEMENT.

(John Marshall.)

The funds available for the work and the expenditure of the Geological Survey for the fiscal year ending March 31, 1912, were:—

Details.	Grant.	Expenditure.
Amounts voted by Parliament	$424,226.50	
Civil List salaries		122,464.87
Explorations in British Columbia and Yukon		36,257.71
Topographical Surveys in British Columbia		14,706.16
Explorations in Northwest Territories		7,289.47
Topographical Surveys in Northwest Territories		9,177.61
Explorations in Ontario		11,897.83
Topographical Surveys in Ontario		1,574.73
Explorations in Quebec		7,405.70
" New Brunswick		2,511.36
Topographical Surveys in New Brunswick		5,579.62
Explorations in Nova Scotia		3,901.56
Ethnological investigations		4,267.32
Turtle Mountain investigation		5,141.76
Explorations in general		2,155.15
Fitting up launch Dawson		583.00
Publications of maps		8,344.36
" reports		8,276.52
Printing, stationery, books, etc		11,087.42
Instruments and repairs		6,767.07
Miscellaneous		3,927.78
Wages, temporary employees		2,397.20
Photographic supplies		1,349.28
Specimens for Museum		8,350.45
Travelling expenses		1,714.78
Advertising		880.00
Clothing for firemen		423.50
Balance unexpended and lapsed		135,794.29
	$424,226.50	$424,226.50

All of which is respectfully submitted.

I have the honour to be, sir,

Your obedient servant,

(signed) R. W BROCK.

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Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

Memoirs and Reports Published During 1910

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

MEMOIRS—GEOLOGICAL SERIES.

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